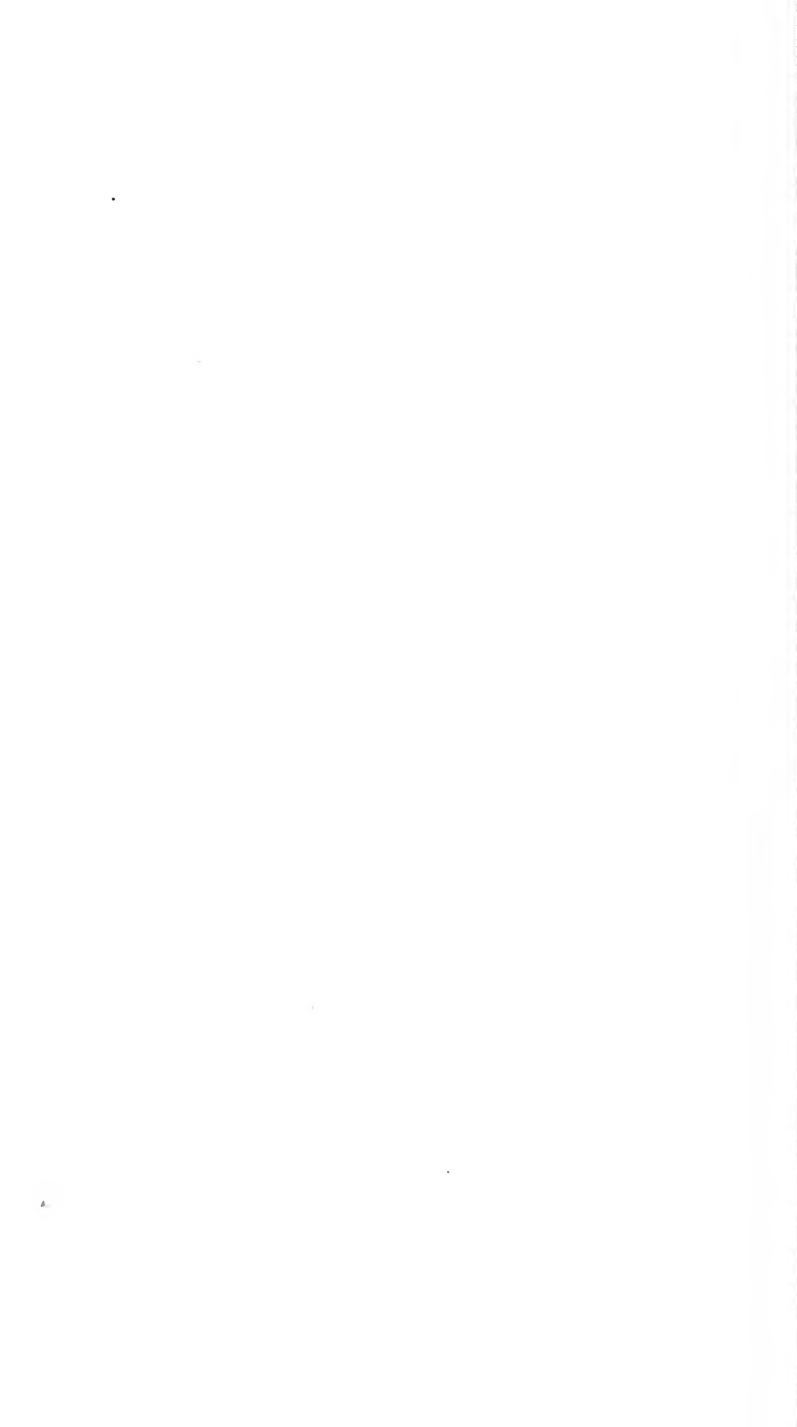


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A

COMPLETE TREATISE
ON
ELECTRICITY,
IN
THEORY AND PRACTICE;
WITH
ORIGINAL EXPERIMENTS.

By TIBERIUS CAVALLO, F.R.S.

THE THIRD EDITION,
IN TWO VOLUMES,
Containing the PRACTICE of MEDICAL ELECTRICITY,
besides other ADDITIONS and ALTERATIONS.

VOLUME II.

LONDON:
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A

COMPLETE TREATISE

ON

ELECTRICITY.

PART IV.

NEW EXPERIMENTS IN ELECTRICITY.

THE laws of Electricity, together with the experiments necessary for their demonstration, having already been described, in as compendious a manner as could be done without obscurity, I shall, in the last Part of this Work, relate such new experiments and observations as I have made at different times, principally with a view to discover, if possible, the unknown cause of several electrical phenomena, especially those relative to atmospheric Electricity.

The first instrument that I made use of to observe the Electricity of the atmosphere, was an electrical kite, which I had constructed, not with a view to observe the Electricity of the air; for this, I thought, was very weak, and seldom to be observed; but as an instrument which could be occasionally used in time of a thunder-storm, in order to observe the Electricity of the clouds. The kite, however, being just finished, together with its string, which contained a brass wire through its whole length, I raised it on the 31st of August 1775, at seven of the clock in the afternoon, the weather being a little cloudy, and the wind just sufficient for the purpose. The extremity of the string being insulated, I applied my fingers to it; which, contrary to my expectation, drew very vivid and pungent sparks: I charged a coated phial at the string several times, but I did not then observe the quality of the Electricity. This successful experiment induced me to raise the kite very often, and to keep it up for several hours together; thinking that if any periodical Electricity, or any change of its quality, took place in the atmosphere, it might very probably be
discovered

discovered by this instrument. In the following two Chapters I shall describe the construction of the electrical kite, with its appurtenances ; and shall transcribe the most remarkable part of my journal relative to the kite ; *i. e.* describing such experiments only as are most remarkable, and do not happen very commonly ; for although I have used my kite sometimes ten, and more times in a week, and at any hour of the day or night, yet as the greatest part of those experiments are only of use to confirm a few laws of atmospherical Electricity, I shall omit their particular detail, and shall only subjoin those laws at the end of the second chapter.

C H A P. I.

The Construction of the electrical Kite, and other Instruments used with it.

THE first electrical kite that I constructed, was seven feet high ; and it was made of paper, with a stick or straiter, and a cane-bow, like the kites commonly used by school-boys. On the upper part of the straiter I fixed an iron spike, projecting about a foot above the kite, which I then thought was absolutely necessary to collect the Electricity ; and I covered the paper of the kite with turpentine, in order to defend it from the rain. This kite, perfect as I thought it to be in its construction, and fit for the experiments for which it was intended, soon manifested its imperfections, and, after being raised a few times, it became quite unfit for farther use ; it being so large, and consequently heavy, that it could not be used, except when the wind was strong ; and then, after much trouble
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in raising and drawing it in, it often received some damage: which soon obliged me to construct other kites upon a different plan, in order to ascertain which method would answer the best for my purpose. I gradually lessened their size, and varied their form, till I observed, upon trial, that a common school-boy's kite was as good an electrical kite as mine. In consequence of which, I constructed my kites in the most simple manner, and in nothing different from the children's kites, except that I covered them with varnish, or with well-boiled linseed-oil, in order to defend them from the rain; and I covered the back part of the straiter with tin-foil, which, however, has not the least power to increase its Electricity. I also furnish the upper extremity of the straiter with a slender wire pointed, which, in time of a thunder-storm, may perhaps draw the Electricity from the clouds somewhat more effectually; but in general, I find, as it will appear in the account of the experiments, that it does not in the least affect the Electricity at the string. The kites that I generally have used are about four feet high, and little above two

feet wide. This size, I find, is the most convenient, because it renders them easy to be managed, and, at the same time, they can draw a sufficient quantity of string. As for silk or linen kites, they require a good deal of wind to be raised; and then they are not so cheap, nor so easy to be made, as paper kites are. The string sometimes breaks, and the kite is lost, or broken; for which reason these kites should be made as cheap and as simple as possible.

The string is the most material part of this apparatus; for the Electricity produced is more or less, according as the string is a better or a worse Conductor. The string which I made for my large kite, consisted of two threads of common twine, twisted together with a brass wire between the strands. This string served very well for two or three trials; but, on examination, I soon found, that the wire in it was broken in many places, and it was continually snapping; the metallic continuation, therefore, being so often interrupted, the string became soon so bad, that it acted nothing better than common twine without a wire.

I at-

I attempted to mend it, by joining the broken pieces of wire, and working into the twine another wire, which proved a very laborious work ; but the remedy had very little effect, the wire breaking again after the first trial ; which determined me to adopt other methods : and, after several experiments, I found that the best string was one, which I made by twisting a copper thread * with two very thin threads of twine. Strings like this I have used for the greatest part of my experiments with the kite, and I find them to be exceedingly useful, and fit for the purpose. Silver or gold thread would do much better to twist with the twine, because they are much thinner than copper thread, and, in consequence, the string would be much lighter ; but, at the same time, it is to be considered, that gold or silver thread is much dearer than copper thread,

I have attempted to render the twine a good Conductor of Electricity, by cover-

* I mean such a thread of copper as is used for trimmings, &c. in imitation of gold threads ; which are nothing more than silk, or linen threads, covered with a thin lamina of copper.

ing it with conducting substances ; as lamp-black, powder of charcoal, very fine emery, and other substances, mixing them with diluted gum-water ; but this method improves the string very little, and for a very short time ; for the said conducting substances are soon rubbed off the twine. Mr. NAIRNE informed me, that he had used to soak the string of his electrical kite in a strong solution of salt, which rendered it a good Conductor, so far as it attracted the moisture of the air. In consequence of this information, I soaked in salt-water a long piece of twine, and, by raising a kite with it, I found that it conducted the Electricity pretty well ; but I thought it much inferior to the above-described string with the copper thread : besides, the salted string in wet weather not only leaves part of the salt upon the hands of the operator, and, in consequence, renders them unfit to manage the rest of the apparatus, but it marks a white spot wherever it touches the clothes.

In raising the kite when the weather is very cloudy and rainy, in which time
there

there is fear of meeting with great quantity of Electricity, I generally use to hang upon the string A B, fig. 9. Plate IV. the hook of a chain C, the other extremity of which falls upon the ground. Sometimes I use another caution besides, which is, to stand upon an insulating stool; in which situation I think, that if any great quantity of Electricity, suddenly discharged by the clouds, strikes the kite, it cannot affect much my person. As to insulated reels, and such-like instruments, that some gentlemen have used to raise the kite, without danger of receiving any shock; fit for the purpose as they may appear to be in theory, they are yet very inconvenient to be managed. Except the kite be raised in time of a thunder-storm, there is no great danger for the operator to receive any shock. Although I have raised my electrical kite hundreds of times without any caution whatever, I have very seldom received a few exceedingly slight shocks in my arms. In time of a thunder-storm, if the kite has not been raised before, I would not advise a person to raise it while the stormy clouds are just overhead; the danger in such time being

being very great, even with the precautions above-mentioned: at that time, without raising the kite, the Electricity of the clouds may be observed by a cork-ball electrometer held in the hand in an open place; or, if it rains, by my electrometer for the rain; which will be described hereafter.

When the kite has been raised, I generally introduce the string through a window in a room of the house, and fasten it to a strong silk lace, the extremity of which is generally tied to a heavy chair in the room. In fig. 8. of Plate III. AB represents part of the string of the kite which comes within the room; C represents the silk lace; DE, a small prime Conductor, which, by means of a small wire, is connected with the string of the kite; and F represents the quadrant electrometer, fixed upon a stand of glass covered with sealing-wax, which I used to put near the prime Conductor, rather than to fix it in a hole upon the Conductor, because the string AB sometimes shakes so as to pull the prime Conductor down; in which case the quadrant electrometer remains

mains safe upon the table ; otherwise it would be broken, as I have often experienced before I thought of this method. G represents a glass tube, about eighteen inches long, with a knobbed wire cemented to its extremity ; with which instrument I use to observe the quality of the Electricity, when the Electricity of the kite is so strong that I think it not safe to come very near the string. The method is as follows :—I hold the instrument by that extremity of the glass tube which is the farthest from the wire, and touch the string of the kite with the knob of its wire, which, being insulated, acquires a small quantity of Electricity from it ; which is sufficient to ascertain its quality when the knob of the instrument is brought near an electrified electrometer.

Sometimes, when I raise the kite in the night-time, out of the house, and where I have not the convenience of observing the quality of its Electricity by the attraction and repulsion, or even by the appearance of the electric light, I make use of a coated phial, which I can charge at the string, and, when charged,

ed, put it into my pocket; wherein it will keep charged even for several hours *. By making use of this instrument, I am obliged to keep the kite up no longer than is necessary to charge the phial, in order to observe the quality of the Electricity in the atmosphere; for after the kite has been drawn in

* The construction of this phial is as follows:— Besides the coating of the inside and outside, that this phial has, like any other of the same kind, a glass tube, open at both ends, is cemented into its neck, and proceeds within the phial, having a small wire fastened to its lower extremity, which touches the inside non-electric coating. The wire with the knob of this phial is cemented into another glass tube, which is nearly twice as long, and smaller than the tube cemented into the neck of the phial. The wire is cemented so, that only its knob projects out of one end, and a small length of it out of the other end of the tube. If this piece with the wire be held by the middle of the glass tube, it may be put in or out of the tube which is in the neck of the phial, so as to touch the small wire at the lower extremity of it, and that without discharging the phial, if it is charged. I have kept such a phial charged for six weeks together; and probably it would keep much longer, if it were to be tried. The ingenious young Electrician may make use of such a phial for several diverting purposes.—The piece of glass which serves to hold the wire by, is rather better to be fixed above than below the ball. In this case, the ball is perforated quite through, and the wire projects a short way above it; to which the glass tube is cemented.

and brought home, I can then examine the Electricity of the inside of the phial, which is the same as that of the kite.

When the Electricity of the kite is very strong, I fix a chain, communicating with the ground, at about six inches distance from the string; which may carry off its Electricity, in case that this should increase so much as to put the by-standers in danger.

Besides the above-described apparatus, I have occasionally used some other instruments, which I have often varied, according as some particular experiments required; but, as they are of no great consequence, I shall omit to describe them. It is only necessary, before I enter into the narration of the principal experiments performed with the kite, to give an idea of the standard of my quadrant electrometer; which may, very probably, shew the same intensity of Electricity under a number of degrees different from the other instrument of the same kind. When the kite is flying, and the apparatus is disposed as in fig. 8. of
Plate

Plate III, I bring, under the extremity E of the prime Conductor, a little bran, held upon a tin plate, and observe, that when the index of the electrometer is at ten degrees, the prime Conductor begins to attract the bran at the distance of about three-fifths of an inch; when the index is at twenty degrees, the prime Conductor attracts the bran at the distance of about one inch and a quarter; when the index is at thirty degrees, the bran begins to be attracted at the distance of two inches and one-fifth. These distances vary, as the weather changes its degree of dryness; but in frosty weather I observe them constantly as above.

C H A P. II.

Experiments performed with the electrical Kite.

September the 2d, 1775. The weather being very cloudy, and actually raining, the kite was raised at eight o'clock P. M. with two hundred yards of string, which had a brass wire through its whole length. The wind was from the south and very strong. The Electricity at the string was negative, and just sufficient to charge a half-pint phial so as to give a shock sensible to the elbows. The kite, after being up for about one hour, fell to the ground, having its paper, which was not properly varnished, almost entirely torn off by the violence of the wind and the rain.

September the 14th. The kite was raised with a strong north wind at half past three P. M. The Electricity was positive,
and

and pretty strong, the index of the electrometer being generally about 20° *. The weather was rather cold, and very thick clouds were gradually approaching the zenith. The kite was pulled down at half past four P. M.

N. B. At night the aurora borealis was very strong, and several flashes of lightning were seen near the horizon towards the north.

September the 23d. A small kite was raised at half past ten o'clock in the morning, and it was kept up for eleven hours successively, *viz.* till half past nine P. M. The string, which was only a common twine, without a wire, was constantly electrified positively, although in a very small degree. About nine o'clock the Electricity appeared stronger, so that a small phial, charged at the string, gave a pretty sensible shock. The weather was very clear, and warm; but in the night no aurora bo-

* The index of the electrometer in general rises higher or falls lower, according as the kite comes nearer to, or goes farther from the zenith; the length of the string remaining the same.

realis,

realis, or any other electrical appearance, was perceived. The wind was east by south, and so weak that the kite was kept up with great difficulty.

October the 10th, 1775. The weather being clear, and the wind blowing strong from the south west, the kite was raised at eleven o'clock A. M. with ninety yards of string, which had a copper thread twisted in*. The wind, during the experiment, increased and decreased several times; and the Electricity, which was positive, as it appeared by the index of the electrometer, also increased and decreased. At noon the violence of the wind caused the kite to fall. At half past four o'clock, the wind being a little more moderate, the kite was raised again. The Electricity was also positive, and seemed rather stronger than it had been in the morning. The weather at this time was cloudy; the clouds appearing much thicker near the horizon than about the zenith. The kite was pulled down at half

* Such string as this was used in all the following experiments.

past five o'clock, and at half after seven was raised again; every phenomenon continuing the same. At eight o'clock, while I was pulling the kite in, I insulated the string when only thirty-five yards of it were out, and was surprised to find, that now the Electricity was as strong as it had been, when all the string was out, which was ninety yards long. It must however be remarked, that at this time a few flashes of lightning were seen among the clouds, which were pretty thick about the horizon. At a quarter past eleven o'clock the kite was raised again, which was the fourth time of raising it that day; the weather then being very clear, and the wind the same as in the afternoon. The Electricity was very weak, but constantly positive. The kite was pulled down, after having been up a few minutes only.

October the 16th. At about two P. M. a thick fog being just cleared up, the weather became clear, and the wind began to blow from the south-south-west. The kite was raised with one hundred and twenty yards of string, and it was kept up no longer

longer than a quarter of an hour. The Electricity was positive, and pretty strong; the index of the electrometer being about 15° . At half past three o'clock the kite was raised again, the weather being very little cloudy. At half past four o'clock the clouds became very thick, and in a short time it began to rain, which increased the Electricity of the kite, without changing its quality; the index of the electrometer arriving to 20° . The kite was pulled down at five o'clock.

October the 18th. After having rained a great deal in the morning, and night before, the weather became a little clear in the afternoon, the clouds appearing separated, and pretty well defined. The wind was west, and rather strong, and the atmosphere in a temperate degree of heat. In these circumstances, at three P. M. I raised my electrical kite with three hundred and sixty feet of string. After that the end of the string had been insulated, and a leather-ball, covered with tin-foil, had been hung to it, I tried the power and quality of the Electricity, which ap-

peared to be positive, and pretty strong. In a short time a small cloud passing over, the Electricity increased a little; but the cloud being gone, it decreased again to its former degree. The string of the kite was now fastened by the silk lace to a post in the yard of the house wherein I lived, which was situated near Islington, and I was repeatedly charging two coated phials, and giving shocks with them:—while I was so doing, the Electricity, which was still positive, began to decrease, and in two or three minutes time it became so weak, that it could be hardly perceived with a very sensible cork-ball electrometer. Observing at the same time that a large and black cloud was approaching the zenith (which, no doubt, caused the decrease of the Electricity) indicating imminent rain, I introduced the end of the string through a window, in a first-floor room, wherein I fastened it by the silk lace to an old chair. The quadrant electrometer was set upon the same window, and was, by means of a wire, connected with the string of the kite. Being now three quarters of an hour after three o'clock, the Electricity was absolutely

lutely unperceivable ; however, in about three minutes time, it became again perceivable, but now upon trial was found to be negative ; it is therefore plain, that its stopping was nothing more than a change from positive to negative, which was evidently occasioned by the approach of the cloud, part of which by this time had reached the zenith of the kite, and the rain also had begun to fall in large drops.—The cloud came farther on ;—the rain increased, and the Electricity keeping pace with it, the electrometer soon arrived to 15° . Seeing now, that the Electricity was pretty strong, I began again to charge the two coated phials, and to give shocks with them ; but the phials had not been charged above three or four times, before I perceived that the index of the electrometer was arrived to 35° , and was keeping still increasing. The shocks now being very smart, I desisted from charging the phials any longer ; and, considering the rapid advance of the Electricity, thought to take off the insulation of the string, in case that if it should increase farther, it might be silently conducted to the earth, without causing

any bad accident, by being accumulated in the insulated string. To effect this, as I had no proper apparatus near me, I thought to remove the silk lace, and fasten the string itself to the chair ; accordingly, I disengaged the wire that connected the electrometer with the string ; laid hold of the string ; untied it from the silk lace, and fastened it to the chair ; but while I effected this, which took up less than half a minute of time, I received about a dozen, or fifteen, very strong shocks, which I felt all along my arms, in my breast, and legs ; shaking me in such a manner, that I had hardly power enough to effect my purpose, and to warn the people in the room to keep their distance. As soon as I took my hands off the string, the Electricity (in consequence of the chair being a bad Conductor) began to snap between the string and the shutter of the window, which was the nearest body to it. The snappings, which were audible at a good distance out of the room, seemed first isochronous with the shocks which I had received, but in about a minute's time, oftner ; so that the people of the house compared their sound to the rattling noise of a
jack

jack going when the fly is off. The cloud now was just over the kite; it was black, and well defined, of almost a circular form, its diameter appearing to be about 40° ; the rain was copious, but not remarkably heavy. As the cloud was going off, the electrical snapping began to weaken, and in a short time became unaudible. I went then near the string, and finding the Electricity weak, but still negative, I insulated it again, thinking to keep the kite up some time longer; but observing that another larger and denser cloud was approaching apace towards the zenith, as I had then no proper apparatus at hand, to prevent every possible bad accident, I resolved to pull the kite in; accordingly a gentleman, who was by me, began pulling it in, while I was winding up the string. The cloud was now very nearly over the kite, and the gentleman, who was pulling in the string, told me, that he had received one or two slight shocks in his arms, and that if he were to feel one more, he would certainly let the string go; upon which I laid hold of the string, and pulled the kite in as fast as I

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could,

could, without any farther observation ; being then ten minutes after four o'clock.

N. B. There was neither thunder or lightning perceived that day, nor indeed for some days before or afterwards.

November the 8th, 1775. The wind being north-west, and just sufficient, the kite was raised at three quarters past eleven A. M. with one hundred and twenty yards of string. The Electricity was positive, and weak, the weather being cloudy. At noon the clouds grew thicker, and the Electricity quite vanished ; however, in a few seconds it returned, and from this time it evidently kept increasing and decreasing, according as the clouds became thinner or thicker. At forty minutes after one o'clock the Electricity vanished again ; a thick cloud then covering almost the whole hemisphere ; but as a little rain began to fall, the Electricity returned, and it was still positive. At three quarters past three o'clock the clouds began to grow thin, and the Electricity increased a little ; but at this time I was obliged to pull the
kite

kite in. The index of the electrometer in this experiment seldom arrived to 6° .

November the 16th. The weather being very clear and frosty, the kite was raised at a quarter past ten A. M. with one hundred and twenty yards of string. The Electricity was positive, and pretty strong, the index of the electrometer going from 9° to 15° ; raising as the wind blew stronger, and the kite was more elevated, and *vice versa*. At a quarter past three o'clock the wind, which was north-north-west, intirely failing, the kite fell.

November the 17th. The weather being exceedingly damp, and the fog so dense, that the houses at about a quarter of a mile distance could not be distinguished, the kite was raised at two P. M. with one hundred and ten yards of string, while it was raining, but very little. The Electricity was positive, and so weak that the cork-balls of an electrometer diverged about three quarters of an inch. The wind being very violent, I was obliged to pull the kite in, after having been up for about five minutes.

December

December the 5th, 1775. The weather being equally cloudy, and the wind west by north, and hardly sufficient, the kite was raised at a quarter past three P. M. with one hundred and twenty yards of string. The Electricity was positive, and so weak as to cause the cork-balls of an electrometer to diverge about an inch. At a little after four o'clock the kite was pulled in; and at eight o'clock in the evening it was raised again. At this time the Electricity was much stronger than in the afternoon, but constantly positive. The weather clearing up, the clouds were driven away by the wind, which was now a little stronger than in the afternoon. At forty minutes after eight o'clock the sky was clear, the moon and stars appearing very bright; except that a few thin clouds were yet to be seen near the horizon. The index of the electrometer was now going from 15 to 20°. At ten minutes after nine o'clock the kite was drawn in.

N. B. No aurora borealis was to be seen.

December

December the 20th. The weather being cloudy and hazy, the kite was raised at three quarters after ten o'clock A. M. with one hundred and forty yards of string. The Electricity was positive, and pretty strong, the index of the electrometer going from 16° to 21° . At half past one P. M. the weather growing a little clearer, I pulled the kite down; and, after having interposed a silk ribband between its loop and the extremity of the string, so as to insulate the kite, I raised it again with the same length of string; and, after I had insulated the lower extremity of the string, I observed that the intensity of the Electricity, as it appeared by the index of the electrometer, was, as nearly as could be determined, the same as before, *i. e.* when the kite was not insulated with respect to the string.

At two o'clock P. M. I pulled the kite down, and found, upon observation, that the silk ribband had contracted no moisture, so that the kite was perfectly insulated by it. This experiment of insulating the kite I have often repeated at other times, and

have always met with the same success; hence it appears, that it is the string, and not the kite, which in general collects the Electricity from the air. The kite therefore in general is only useful to extend the string high into the open air.

January the 4th, 1776. The frost having been very hard during the day and night before, the wind began to blow very strong from the south at two o'clock A. M. which occasioned a sudden thaw and a copious rain. At eight o'clock A. M. at which time the kite was raised, the hemisphere appeared like a uniform dark canopy, under which several small, irregular, and darker clouds were running very fast; the rain was constant, but not remarkably heavy. As soon as the string of the kite was insulated, the Electricity, which was negative, began to snap from it, to the shutter of the window and other bodies near; the index of the electrometer arrived to 40° , and it would have certainly gone farther, if the apparatus had been drier; but the air was so damp, that it was almost impossible to keep any part of the apparatus

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tus sufficiently free from moisture. The Electricity, however, gradually decreased, so that at ten o'clock A. M. at which time the kite was pulled in, the index of the electrometer was at a little above 12° . The coated phials in this experiment were charged surprisingly quick; three or four seconds of time being sufficient to charge two half-pint phials completely.

January the 11th. The ground was covered with ice and snow, and the atmosphere was so hazy, that the houses at a mile distance could not be perceived. The wind was south-east by south, and just sufficient to raise the kite, which was raised at three o'clock P. M. with one hundred and twenty-four yards of string, and kept up till half an hour after midnight. When the kite was first raised it began to thaw, but as soon as it was dark it began to freeze again very hard. The Electricity was positive, and pretty strong, the index of the electrometer being about 13° . At half past four o'clock I let out thirty-four yards more of string, so that all the string the kite now had, was one hundred and fifty-eight yards.

yards. With this addition of string the Electricity increased, so that the index of the electrometer arrived to 17° . At half after five o'clock the wind began to increase, and the Electricity to decrease, until the index of the electrometer arrived to 6° . At three quarters past six o'clock the index of the electrometer was about 13° , and at seven o'clock it arrived to 20° ; the wind being now quite east. At a quarter past seven o'clock the index of the electrometer was about 25° . From this time the wind and the Electricity began both to decrease, so that at nine o'clock the index of the electrometer was about 10° . At eleven o'clock the wind increased. At twelve o'clock the wind was very strong, and the index of the electrometer was about 6° . At half past twelve o'clock the index of the electrometer was between 3° and 4° ; but the wind being grown very violent, the string broke very near the window, and was lost with the kite.

N. B. A few minutes after the kite was lost, it began to snow copiously.

January

January the 26th. The frost being very intense, as it had been for about three weeks, and actually snowing, I raised the kite, with seventy yards of string; but before the string was insulated, it ceased to snow, and the weather began to clear up, and soon became very serene. The Electricity was positive, and very strong, the index of the electrometer being about 32° . At eleven o'clock the string broke, and the kite fell, after having been up for above three quarters of an hour.

February the 17th, 1776. The weather being cloudy, rainy, and so hazy, that the houses at half a mile distance could not be discerned, the kite was raised at three quarters past eleven o'clock A. M. with one hundred and seventy-five yards of string. The wind was pretty strong; the Electricity was negative, and also strong; the index of the electrometer being about 20° . In about five minutes time the rain ceased, the wind weakened, and shifted a little towards the south; and the Electricity changed from negative to positive. The index of the electrometer was now
about

about 15° . In two or three minutes time, it began to rain again, and continued so for the greatest part of that day; the wind became very weak, and the Electricity changed again from positive to negative, and continued so till half an hour after noon; at which time the wind became so weak that I was obliged to pull the kite in.

February the 19th. The sky being full of pretty well defined clouds, and the wind west-north-west, the kite was raised at half past three o'clock P. M. with one hundred and seventy-five yards of string. The Electricity was positive and strong, the index of the electrometer going from 10° to 20° . At three quarters past three o'clock a dense cloud passed over the kite, which occasioned the index of the electrometer to descend to 4° . As the cloud went away, the electrometer elevated its index. At four o'clock the kite was pulled down.

April the 8th, 1776. The weather was clear, and the northern light very strong.
The

The kite was raised for a few minutes at nine o'clock P. M. with one hundred and seventy-five yards of string, the wind being north-north-west, and pretty strong. The Electricity was positive, and, as I could judge, the index of the electrometer would have arrived to 15° .

May the 15th, 1776. The weather being cloudy, and the wind north, the kite was raised at three o'clock P. M. with one hundred and seventy yards of string. The Electricity was at first exceedingly weak, and, as I imagine (for I had not time to examine it) positive. But a dense cloud passing over the kite, the Electricity vanished; and, as a few drops of rain fell, a very weak negative Electricity appeared, which soon increased, so as to cause the index of the electrometer to arrive to 15° . The rain, however, in a few minutes ceased, and the Electricity gradually decreased and vanished. A very weak positive Electricity immediately took place; but, as another denser cloud passed over, and a few very small drops of rain fell, the positive Electricity vanished, and the ne-

gative took place. The cloud and rain soon went off, and the Electricity became again positive, and continued so till the kite was pulled down. According as the clouds, which passed continually over the kite, were thinner or thicker, so the Electricity was more or less intense; sometimes causing the index of the electrometer to arrive to 5° , and at other times being scarce perceivable with the cork-ball electrometer. At five o'clock the kite was pulled in, the weather being then pretty clear, and the index of the electrometer at 3° . The wind, during this experiment, was stronger or weaker, according as the clouds which passed over were thicker or thinner. At half past seven o'clock in the evening of the same day, the kite was raised again, with the same length of string, the wind being then rather strong, and the weather pretty clear. The Electricity was positive, and the index of the electrometer stood at 10° ; but as some clouds came from the north, the Electricity began to decrease, and by eight o'clock it just separated the balls of an electrometer, the hemisphere being then entirely covered by clouds. At half

past eight o'clock the kite was pulled down, the clouds over the kite being then very thin, and the index of the electrometer at 5° .

June the 4th, 1776. The weather being cloudy, and the wind on the south-south-west, the kite was raised at one o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive, and the index went from 1° to 7° . At three quarters past one o'clock the clouds began to be dissipated, and the Electricity increased a little. At two o'clock the kite was pulled in.

June the 17th. The weather being cloudy, and the wind south-west, the kite was raised at five o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive, and the index of the electrometer went from 10° to 16° . In this experiment the clouds, whether thicker or thinner, seemed to have no effect upon the Electricity of the kite. At a quarter past six o'clock the kite was pulled in.

June the 20th. The weather being cloudy, and the wind east, and just sufficient, the kite was raised at three quarters past three P. M. with one hundred and seventy yards of string. The Electricity was positive, and the index of the electrometer stood about 8° . At five o'clock the weather began to clear up, and the Electricity to increase; so that in half an hour's time, the index of the electrometer arrived to 17° ; and at six o'clock it stood at 25° . But the wind suddenly failing about this time, the kite fell.

January the 8th, 1777. The weather being frosty and clear, and the wind north, and pretty strong, the kite was raised at four o'clock P. M. with one hundred and seventy yards of string. The Electricity was positive and strong, the index of the electrometer being at 36° . The spark taken from the small prime Conductor was remarkably pungent in this experiment, although it was hardly a quarter of an inch long. At a quarter past five o'clock the kite was pulled in.

General

*General Laws, deduced from the Experiments
performed with the electrical Kites.*

I. The air appears to be electrified at all times ; its Electricity is constantly positive, and much stronger in frosty, than in warm weather * ; but it is by no means less in the night than in the day-time †.

II. The presence of the clouds generally lessens the Electricity of the kite : sometimes it has no effect upon it ; and it is very seldom that it increases it a little,

* My observations upon the Electricity of the atmosphere have been made in almost every degree of temperature, from 15° to 80° of FARENHEIT's thermometer.

† In all my experiments, it happened only once that the string of the kite gave no signs of Electricity ; it was one afternoon, when the weather was warm, and the wind so weak, that the kite was raised with difficulty, and could hardly be kept up for a few minutes ; in the evening, however, the wind, which in the day-time had been north-west, shifted to the north-east, blowing a little stronger ; I then raised the kite again, being half past ten o'clock, and obtained, as usual, a pretty strong positive Electricity.

III. When it rains, the Electricity of the kite is generally negative, and very seldom positive.

IV. The aurora borealis seems not to affect the Electricity of the kite.

V. The electrical spark taken from the string of the kite, or from any insulated Conductor connected with it, especially when it does not rain, is very seldom longer than a quarter of an inch ; but it is exceedingly pungent. When the index of the electrometer is not higher than 20° , the person that takes the spark will feel the effect of it in his legs ; it appearing more like the discharge of an electric jar, than the spark taken from the prime Conductor of an electrical machine.

VI. The Electricity of the kite is in general stronger or weaker, according as the string is longer or shorter ; but it does not keep any exact proportion to it : the Electricity, for instance, brought down by a string of a hundred yards, may raise the index of the electrometer to 20° ; when,
with

with double that length of string, the index of the electrometer will not go higher than 25° .

VII. When the weather is damp, and the Electricity is pretty strong, the index of the electrometer, after taking a spark from the string, or presenting the knob of a coated phial to it, rises surprisingly quick to its usual place; but in dry and warm weather, it rises exceeding slow.

These few laws are, in short, the deduction of all my experiments performed with the kites, during the course of about two years. How far they may be of use, or may coincide with the observations of other experimentators, I will not pretend to say. My experiments have been performed at Islington, and perhaps the result of similar ones may be different at other places, especially under different climates; I wish, therefore, that they may be accurately repeated in other places, and their result may be compared together; in order to determine, if possible, something satisfactory, relative to the cause of that perpetual

Electricity which exists in the atmosphere, and which, very probably, occasions the Electricity of the clouds.

C H A P. III.

Experiments performed with the Atmospheric Electrometer, and the Electrometer for the Rain.

F I G. 1. of Plate III, represents a very simple instrument, which I have contrived for the purpose of making observations on the Electricity of the atmosphere; and which, on several accounts, seems to be the most useful for that purpose. A B is a common jointed fishing-rod, without the last or smallest joint. From the extremity of this rod proceeds a slender glass tube C, covered with sealing-wax, and having a cork D, at its end, from which a pith-ball electrometer is suspended. H G I is a piece of twine fastened to the other extremity of the rod, and supported at G by a small string F G.

At

At the end I of the twine a pin is fastened, which, when pushed into the cork D, renders the electrometer E uninsulated.

When I would observe the Electricity of the atmosphere with this instrument, I thrust the pin I into the cork D, and holding the rod by its lower end A, project it out from a window in the upper part of the house into the air, raising the end of the rod with the electrometer, so as to make an angle of about 50° or 60° with the horizon. In this situation I keep the instrument for a few seconds, and then pulling the twine at H, I disengage the pin from the cork D; which operation causes the string to drop in the dotted situation KL, and leaves the electrometer insulated and electrified, with an Electricity contrary to that of the atmosphere.—This done, I draw the instrument into the room, and examine the quality of the Electricity, without obstruction either from wind or darkness.

With this instrument I have made observations on the Electricity of the atmosphere,

sphere, several times in a day for several months, and from them I have deduced the following general observations, which seem to coincide with those made with the electrical kites.

I. That there is in the atmosphere, at all times, a quantity of Electricity ; for, whenever I use the above-described instrument, it always acquires some Electricity.

II. That the Electricity of the atmosphere, or fogs, is always of the same kind, namely positive ; for the electrometer is always negative, except when it is evidently influenced by heavy clouds near the zenith ; as appears by the observations made the 19th of October, in the following specimen of the journal.

III. That in general, the strongest Electricity is observable in thick fogs, and also in frosty weather ; and the weakest, when it is cloudy, warm, and very near raining : but it does not seem to be less by night than in the day time.

IV. That

IV. That in a more elevated place the Electricity is stronger than in a lower one ; for, having tried the atmospherical electrometer, both in the stone and iron gallery in the cupola of St. Paul's Cathedral, I found that the balls diverged much more in the latter than in the former less elevated place ; hence it appears, that, if this rule takes place at any distance from the earth, the Electricity in the upper regions of the atmosphere must be exceedingly strong.

The electrometer for the rain, in principle is nothing more than an insulated instrument to catch the rain, and by a pith-ball electrometer to shew the quantity and quality of its Electricity.

Fig. 2. of Plate III. represents an instrument of this kind, which I have frequently used, and after several observations, have found to answer very well. A B C I is a strong glass tube about two feet and a half long, having a tin funnel, D E, cemented to its extremity, which funnel defends part of the tube from the rain. The outside surface of the tube from A to B is covered with sealing-wax; so also is the part of it which is covered by the funnel. F D is a piece of cane, round which several brass wires are twisted in different directions, so as to catch the rain easily, and at the same time, to make no resistance to the wind. This piece of cane is fixed into the tube, and a slender wire proceeding from it goes through the bore of the tube, and communicates with the strong wire A G, which is thrust into a piece of cork fastened to the end A of the tube. The end G of the wire A G is formed into a ring, from which
I suspend

I suspend a more or less sensible pith-ball electrometer, as occasion requires.

This instrument is fastened to the side of the window-frame, where it is supported by strong brass hooks at CB, which part of the tube is covered with a silk lace, in order to adapt it better to the hooks. The part FC is out of the window, with the end F a little elevated above the horizon. The remaining part of the instrument comes through a hole in one of the lights of the sash, within the room, and no more of it touches the side of the window than the part CB.

When it rains, especially in passing showers, this instrument, standing in the situation above described, is frequently electrified; and, by the diverging of the electrometer, the quantity and quality of the Electricity of the rain may be observed, without any danger of a mistake. With this instrument I have observed, that the rain is generally, though not always, electrified negatively, and sometimes so strongly that I have been able to charge a small coated phial at the wire AG.

This

This instrument should be fixed in such a manner, that it may be easily taken off from the window, and replaced again, as occasion requires; for it will be necessary to clean it very often, particularly when a shower of rain is approaching.

I shall conclude this chapter with the description of a pocket electrometer, fig. 5 and 6. of Plate III. that I have lately constructed, and which, on several accounts, seems preferable to those of the most sensible sort now in use. The case, or handle of this electrometer is formed by a glass tube, about three inches long, and three-tenths of an inch in diameter, half of which is covered with sealing-wax. From one extremity of this tube, *i. e.* that without sealing-wax, a small loop of silk proceeds, which serves occasionally to hang the electrometer on a pin, &c. To the other extremity of the tube a cork is adapted, which, being cut tapering on both ends, can fit the mouth of the tube with either end. From one extremity of this cork, two linen threads proceed, a little shorter than the length of the tube, suspending each a little *cone* of pith of elder. When
this

this electrometer is to be used, that end of the cork which is opposite to the threads is pushed into the mouth of the tube; then the tube forms the insulated handle of the pith electrometer, as represented fig. 6. Plate III. But when the electrometer is to be carried in the pocket, then the threads are put into the tube, and the cork stops it, as represented fig. 5. The peculiar advantages of this electrometer are, its convenient small size, its great sensibility, and its continuing longer in good order than any other I have yet seen.

Fig. 4. of Plate III. represents a case to carry the above-described electrometer in. This case is like a common tooth-pick case, except that it has a piece of amber fixed on one extremity A, which may occasionally serve to electrify the electrometer negatively, and on the other extremity it has a piece of ivory fastened upon a piece of amber BC. This amber BC serves only to insulate the ivory, which, when insulated, and rubbed against woollen cloths, acquires a positive Electricity; and it is therefore useful to electrify the electrometer positively.

C H A P. IV.

Experiments made with the Electrophorus, commonly called a Machine for exhibiting perpetual Electricity.

IN fig. 9. of Plate III. there are represented some Plates, commonly called the Machine for exhibiting perpetual Electricity, or the *Electrophorus*. This machine consists of two plates, one of which, B, is a circular glass plate, covered on one side with some sulphureous or resinous electric, most commonly with a composition made of equal parts of rosin, shell-lac, and sulphur; the other plate A, is a brass plate, or a board covered with tin-foil, which is nearly of the same dimensions as the electric plate, and it is furnished with a glass handle I, which, by means of a brass or wooden socket, is screwed into its center. This machine is the invention of an Italian philosopher (Mr. VOLTA of Como) and its use is the following :

First, the plate B is excited, by rubbing its coated side with a piece of new white flannel, and when excited as much as possible, is set upon the table with the coated side uppermost. Secondly, the metal plate is laid upon the excited electric, as represented in the figure. Thirdly, the metal plate is touched with the finger or any other Conductor, which, on touching the plate, receives a spark from it. Lastly, the metal plate A, being held by the extremity of its glass handle I, is separated from the electric plate; and, after it is elevated above that plate, it will be found strongly electrified, with an Electricity contrary to that of the electric plate, in which case it will give a very strong spark to any Conductor brought near it. By setting the metal upon the electric plate, touching it with the finger, and separating it successively, a great number of sparks may be obtained apparently of the same strength, and that without exciting again the electric plate. If these sparks are repeatedly given to the knob of a coated phial, this will presently become charged.

The action of these plates depends upon a principle long ago discovered, *viz.* the power that an excited electric has to induce a contrary Electricity in a body brought within its sphere of action; the metal plate, therefore, when set upon the excited electric, acquires a contrary Electricity, by giving its electric fluid to the hand, or other Conductor that touches it, when set upon a plate positively electrified; or acquiring an additional quantity of fluid from the hand, &c. when set upon a plate electrified negatively.

As to the continuance of the virtue of this electric plate, when once excited, without repeating the excitation, I think there is not the least foundation for believing it perpetual, as some persons have supposed; it being nothing more than an excited electric, it must gradually lose its power, by imparting continually some of its Electricity to the air, or other substances contiguous to it. Indeed its Electricity, although it could never be proved to be perpetual by experiments, lasts a very long time, it having been observed to be pretty strong

several days, and even weeks after excitation. The great duration of the Electricity of this plate, I think, depends upon two causes: first, because it does not lose any Electricity by the operation of putting the metal plate upon it, &c.; and secondly, because of its flat figure, which exposes it to a less quantity of air, in comparison with a stick of sealing-wax, or the like, which being cylindrical, exposes its surface to a greater quantity of air, which is continually robbing the excited electrics of their virtue.

The first experiments that I made relative to this machine, were with a view to discover which substance would answer best for coating the glass plate, in order to produce the greatest effect. I tried several substances either simple or mixed, and at last I observed, that the strongest in power, as well as the easiest I could construct, were those made with the second sort of sealing-wax *, spread upon a thick plate of glass.

* It is remarkable, that sometimes they will not act well at first; but they may be rendered very good, by scraping with the edge of a knife the shining or glossy

glass †. A plate that I made after this manner, and no more than six inches in diameter, when once excited, could charge a coated phial several times successively, so strong as to pierce a hole through a card with the discharge. Sometimes the metal plate, when separated from it, was so strongly electrified, that it darted strong flashes to the table upon which the electric plate was laid, and even into the air, besides causing the sensation of the spider's web upon the face brought near it, like an electric strongly excited. The power of some of my plates is so strong, that sometimes the electric plate adheres to the metal, when this is lifted up; nor will they separate, even if the metal plate is by surface of the wax. This seems analogous to the well-known property of glass; which is, that new cylinders or globes, made for electrical purposes, are often very bad electrics at first, but that they improve by being worked, *i. e.* by having their surface a little worn. Paper also has nearly the same property.

† I have lately seen some of those plates, constructed by Mr. G. ADAMS, which acted exceedingly well; and they were made with a composition of two parts of shell-lac, and one part of Venice turpentine, without any glass plate.

touched with the finger, or other Conductor.

If, after having excited the sealing-wax, I lay the plate with the wax upon the table, and the glass uppermost, *i. e.* contrary to the common method, then, on making the usual experiment of putting the metal plate on it, and taking the spark, &c. I observe it to be attended with the contrary Electricity; that is, if I lay the metal plate upon the electric one, and while in that situation touch it with an insulated body, that body acquires the positive Electricity, and the metallic, removed from the electric plate, appears to be negative; whereas it would become positive if laid upon the excited wax. This experiment, I find, answers in the same manner, if an electric plate is used which has the sealing-wax coating on both sides, or one of Mr. ADAMS's, which has no glass plate.

If the brass plate, after being separated from, be presented with the edge toward the wax, lightly touching it, and thus be drawn over its surface, I find that the
Electricity

Electricity of the metal is absorbed by the sealing-wax, and thus the electric plate loses part of its power; and if this operation is repeated five or six times, the electric plate loses its power intirely, so that a new excitation is necessary in order to revive it.

If, instead of laying the electric plate upon the table, it is placed upon an electric stand, so as to be accurately insulated, then the metal plate set on it acquires so little Electricity that it can only be discovered with an electrometer; which shews that the Electricity of this plate will not be conspicuous on one side of it, if the opposite side is not at liberty either to part with, or acquire more of the electric fluid. In consequence of this experiment, and in order to ascertain how the opposite sides of the electric plate would be affected in different circumstances, I made the following experiments:

Upon an electric stand E, fig. 9. Plate III. I placed a circular tin plate, nearly six inches in diameter, which by a slender

E 4 wire

wire H communicated with an electrometer of pith-balls G, which was also insulated upon the electric stand F. I then placed the excited electric plate D, of six inches and a quarter in diameter, upon the tin plate, with the wax uppermost, and on removing my hand from it, the electrometer G, which communicated with the tin plate, *i. e.* with the under side of the electric plate, immediately opened with negative Electricity. If, by touching the electrometer, I took that Electricity off, the electrometer did not afterwards diverge. But if now, or when the electrometer diverged, I presented my hand open, or any other uninsulated Conductor, at the distance of about one or two inches, over the electric plate, without touching it, then the pith-balls diverged; or if they diverged before, came together, and immediately diverged again with positive Electricity;—I removed the hand, and the balls came together;—approached the hand, and they diverged; and so on.

If, while the pith-balls diverged with negative Electricity, I laid the metal plate,
 2 holding

holding it by the extremity K of its glass handle, upon the wax, the balls came, for a little time, towards one another, but soon opened again with the same, *i. e.* negative Electricity.

If, whilst the metallic rested upon the electric plate, I touched the former, the electrometer immediately diverged with positive Electricity, which if, by touching it, I took off, the electrometer continued without divergence. — I touched the metal plate again, and the electrometer opened again ; and so on for a considerable number of times, until the metal plate had acquired its full charge. On taking now the metal plate up, the electrometer G instantly diverged with strong negative Electricity.

I repeated the above-described experiments with this only difference in the disposition of the apparatus, *i. e.* I laid the electric plate D, with the excited sealing-wax, upon the circular tin plate, and the glass uppermost ; and the difference in their result was, that where the Electricity had
been

been positive in the former disposition of the apparatus, it now became negative, and *vice versa*; except that, when I first laid the electric plate upon the tin, the electrometer G diverged with negative Electricity, as well in this as in the other disposition of the apparatus.

I repeated all the above-mentioned experiments with an electric plate, which, besides the sealing-wax coating on one side, had a strong coat of varnish on the other side; and their result was similar to that of those made with the above-described plate.

As to the explanation of these experiments, they seem to depend upon these two well-known principles, *viz.* that a body brought within the sphere of action of an electrified body, does actually acquire the contrary Electricity: and that the existence of one kind of Electricity upon the surface of a substance whatever, causes the existence of the contrary Electricity upon some other substance near it.

C H A P. V.

Experiments on Colours.

HAVING accidentally observed that an electric shock, sent over the surface of a card, marked a black stroke upon a red spot of the card, I was from this induced to try what would be the effect of sending shocks over cards painted with different water-colours; accordingly I painted several cards with almost every colour I had, and sent shocks* over them, when they were very dry; making use of the universal discharger, fig. 5. Plate I. The effects were as follow:

Vermilion was marked with a strong black track, about one-tenth of an inch wide. This stroke is generally single, as represented by AB, fig. 7. of Plate III.; sometimes it is divided in two towards the

* The force generally employed was the full charge of one foot and a half of coated glass.

middle,

middle, like EF ; and sometimes, particularly when the wires are set very distant from one another, the stroke is not continued, but interrupted in the middle, like GH. It often, although not always, happens, that the impression is marked stronger at the extremity of that wire from which the electric fluid issues, as it appears at E, supposing that the wire C communicates with the positive side of the jar ; whereas the extremity of the stroke, contiguous to the point of the wire D, is neither so strongly marked, nor surrounds the wire so much as the other extremity E.

Carmine received a faint and slender impression of a purple colour.

Verdigrise was shook off from the surface of the card, except when it had been mixed with strong gum-water, in which case it received a very faint impression.

White lead was marked with a strong black track, not so broad as that on vermilion.

Red

Red lead was marked with a faint mark, much like carmine.

The other colours I tried, were orpiment, gambodge, sap-green, red-ink, ultramarine, Prussian blue, and a few others, which were compounds of the above; but they received no impression.

It having been insinuated, that the strong black mark, which vermilion receives from the electric shock, might possibly be owing to the great quantity of sulphur contained in that mineral, I was induced to make the following experiment:—I mixed together equal quantities of orpiment and flower of sulphur, and with this mixture, by the help, as usual, of very diluted gum-water, I painted a card; but the electric shock sent over it left not the least impression.

Desirous of carrying this investigation on colours a little further, with a particular view to determine something relative to the properties of lamp-black and oil *, I procured

* It has often been observed, that when the lightning has struck the masts of ships, it has passed over such

cured some pieces of paper painted on both sides with oil colours, and sending the charge of two feet of coated glass over each of them, by making the interruption of the circuit upon their surfaces, I observed that the pieces of paper painted with lamp-black, Prussian-blue, vermilion, and purple brown, were torn by the explosion, but white lead, Naples yellow, English ochre, and verdigrise remained unhurt.

The same shock sent over a piece of paper painted very thickly with lamp-black and oil left not the least impression. I sent the shock also over a piece of paper unequally painted with purple brown, and the paper was torn where the paint laid very thin, but remained unhurt where the paint was evidently thicker. These experiments I repeated several times, and with some little variation, which naturally produced

such parts of the masts which were covered with lamp-black and tar, or painted with lamp-black and oil, without the least injury, at the same time that it has shivered the uncoated parts, in such a manner as to render the masts useless. For a particular account of such facts, see the *Phil. Trans.* vol. XLVIII. and LXVII.

different effects; however, they all seem to point out the following proposition.

I. A coat of oil paint, over any substance, defends it from the effects of such an electric shock, as would otherwise injure it; but by no means defends it from any electric shock whatever. II. No one colour seems preferable to the others, if they are equal in substance, and equally well mixed with oil; but a thick coating does certainly afford a better defence than a thinner one.

By rubbing the above-mentioned pieces of paper, I find that the paper painted with *lamp-black and oil* is more easily excited, and acquires a stronger Electricity, than the papers painted with the other colours; and perhaps on this account it may be, that lamp-black and oil might resist the shock somewhat better than the other paints.

It is remarkable, that vermilion receives the black impression, when painted with linseed-oil, nearly as well as when painted with water. The paper painted with white lead and oil, receives also a
black

black mark ; but its nature is very fingular. The track, when first made, is almost as dark as that marked on white lead, painted with water, but it gradually loses its blackness, and in about one hour's time (or longer, if the paint is not fresh) it appears without any darkness ; and when the painted paper is laid in a proper light, appears only marked with a colourless track, as if made by a finger-nail. I sent the shock also over a piece of board, which had been painted with white lead and oil about four years before, and the explosion marked the black track upon this also ; this track however was not so strong, nor vanished so soon as that marked upon the painted paper, but in about two days time it also vanished intirely.

C H A P. VI.

Promiscuous Experiments.

Observing that a strong spark may be obtained from the metal plate belonging to Mr. VOLTA's machine, described in the fourth chapter of this Part, when not the least spark can be obtained from the electric plate itself, I was naturally induced to make use of the above-mentioned metallic plate, to discover the Electricity of very weak electrics; which otherwise would be either inobservable, or so small as not to permit its quality to be ascertained. Accordingly I constructed several such plates of different sizes, beginning from that of a common metal button fastened upon a stick of sealing-wax; and by using them, I obtained a very sensible Electricity from the hairs of my legs, when stroked, and of my head, or any part that I have tried of my body, or the head of almost any other person.

In this manner I obtain such strong sparks from the back of a cat, a hare's skin, a rabbit's skin, a piece of flannel, or of paper, that I can presently charge a coated phial with either of those, and so strongly, as to pierce a hole through a card with its discharge.

I have often observed that, when stroking a cat with one hand, and holding it with the other, I feel frequent smart pricklings on different parts of that hand, which holds the animal. In these circumstances very pungent sparks may be drawn from the tips of the ears of the cat.

Smooth glass rubbed with a rabbit's skin, dry and warm, acquires, I find, the *negative* Electricity; but if the skin is cold, the glass is excited positively. Sometimes smooth glass may be excited negatively with new white flannel, clean and dry, and also with a hare's skin.

Observing the strong electric power of new white flannel, I thought that a piece of it, rolled round the globe of an electrical machine,

machine, would perhaps give a stronger Electricity to the prime Conductor than the glass itself. In order to try the truth of my supposition, I tied a large piece of flannel, dry and warm, round the globe of the machine, and for a rubber, I applied the palm of my hand; then turned the winch, first slowly, and afterwards briskly; but, contrary to my expectation, the Electricity at the prime Conductor, although positive, was so weak, that the index of the quadrant electrometer was not moved from its perpendicular situation. Surprised at this event, I resolved to take off the apparatus; but I was more surprised, when, on removing the flannel from the globe, the former appeared so strongly positive, that it darted several sparks to my arm, and other contiguous bodies, and the latter remained so strongly negative, that the electrometer upon the prime Conductor instantly elevated its index to about 45° . This experiment being several times repeated, produced always the same effect.

Having had occasion to coat a ten ounce phial for the Leyden experiment, I stuck

F 2 . .

the

the brass filings on the inside of it with varnish, agreeable to the directions given by some writers on Electricity. - This phial remained about a week unused, but it happened that whilst I was charging and discharging it for some experiments, on making a discharge, it exploded with a greater noise than usual, the cork with the wire being at the same time blown out of the neck of it. Being intent upon the main experiments in hand, I omitted to examine this phenomenon; — I replaced the cork into the neck of the phial, and went on charging and discharging it again; but it had not been charged above three or four times more, when, on making a discharge, the varnish that stuck the brass filings was in a flame, which burnt the under side of the cork, and occasioned a good deal of smoke and flame to come out of the phial. Some days after, this experiment was repeated in the presence of three gentlemen, well versed in Electricity, when the cork with the wire was also pushed out of the neck of the phial; but the varnish was this last time so far burnt, that the brass filings were almost all dropped to the

the

the bottom of the phial, and had their colour changed by the combustion.

In making some experiments, of a nature rather different from Electricity, I accidentally observed, that when I agitated some quicksilver in a glass tube, hermetically sealed, and in whose cavity the air was very much rarefied, the outside of the tube appeared sensibly electrified; its Electricity however was not constant, nor, as I first thought, in proportion to the agitation of the quicksilver. Being desirous of ascertaining the properties of such tubes, I constructed several of them, and by means of two cork-ball electrometers, observed their properties; but as they all agree in regard to the chief points, I shall only describe one, which is the best of them. This tube is represented by fig. 3. of Plate III. Its length is thirty-one inches, and its diameter is little less than half an inch. The quicksilver in it may be about three fourths of an ounce; and in order to exhaust it of air, I closed it while the quicksilver was boiling in its opposite end.

Before this tube is used, I make it a little warm, and clean it; then holding it nearly horizontal, I let the quicksilver in it run from one end of the tube to the other, by gently and alternately elevating and depressing its extremities. This operation immediately renders the outside of the tube electrical, but with the following remarkable property, *viz.* that end of the tube, where the quicksilver actually stands, is positive, and all the remaining part is negative. If by elevating this positive end of the tube a little, I let the quicksilver run to the opposite end, which was negative, then the former instantly becomes negative, and the latter positive. The positive end has always a stronger Electricity than the negative. If when one end of the tube, for instance A, is positive, *i. e.* when the quicksilver is in it, I do not take off that Electricity by touching it; then on elevating this end A, so as to let the quicksilver run to the opposite end B, it appears negatively electrified in a very small degree. If by depressing it again, it be rendered positive a second time, and that positive Electricity is neither taken off, then on elevat-

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ing this end A again, it appears to be positive in a small degree : but if whilst it is positive, its Electricity be taken off, then on being elevated, it appears strongly negative.

When about two inches of each extremity of this tube is coated with tin-foil as it appears in the figure, that coating assists to render the Electricities at the extremities of the tube more conspicuous, so that sometimes they give sparks to a Conductor brought near.

In regard to the construction of such tubes (which I have made of several lengths, from nine to thirty-one inches) it is observable, that some will act very well, while others will hardly acquire any Electricity at all, even when they are made very hot. I am not yet thoroughly satisfied in respect to this difference, but suspect that the thickness of the glass is more concerned, than any thing else ; it appearing that a tube, whose glass is about one-twentieth of an inch thick, answers better than either a thicker or a thinner one.

The following Chapters contain the account of some experiments, which I made since the first publication of this Book ; for which reason, I deemed proper to relate them apart, without altering the preceding chapters, with the contents of which they are however connected,

C H A P. VII.

An Account of some new Experiments in Electricity, with the Description and Use of two new Electrical Instruments.

PROFESSOR LICHTENBERG of Gottingen, some time ago made an experiment upon the electrophorus, an account of which was first received in London towards the latter end of the year 1777. The phenomena attending the experiment are very entertaining and various, but I do not know that any person ever offered a satisfactory explanation of them. The author himself, in his paper entitled “ *De nova methodo naturam ac motum fluidi electrici investigandi Commentatio prior,*” wherein he

gives

gives an account of the experiment, does not attempt any explanation of it; contenting himself with the account only of various particulars attending it.—In brief, the experiment is as follows :

The electrophorus, that is, a plate of some resinous substance, as sulphur, rosin, gum-lac, &c. is first excited, either by rubbing or otherwise; then a piece of metal of any shape, at pleasure, as for instance, a three-legged compass, a piece of brass tube, or the like, is set upon the electrophorus, and to this piece of metal so placed, a spark is given, of the Electricity contrary to that of the plate; this done, the piece of metal is removed, by means of a stick of sealing-wax or other electric, and some powder of rosin, kept in a linen bag, is shaken upon the electrophorus: this powder will be found to fall about those points upon the plate, which the piece of metal touched, forming some radiated appearances, much like the common representations of stars; at the same time, upon the greatest part of the plate, that is, besides those stars, there is hardly any powder

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at all. Now, it is to be remarked, that if the plate is excited negatively, and the spark given to the metal set upon it is positive, the appearance will be as above-described ; but if, on the contrary, the plate is positive and the spark is negative, then the powder of rosin will be found to fall upon those parts of the plate which in the other case it left uncovered, and to leave the stars clean ; in short, it will do just the reverse of what it did in the other case ; or, in other words, the powder of rosin will be attracted by those parts only of the electrophorus which are electrified positively,

When I first observed these phenomena, I thought there was no apparent reason why the powder of rosin should be attracted by those parts of the electrophorus which are positively electrified, and not by those which are negative. The two Electricities are certainly contrary to one another ; but either of them attracts a non-electrified body. Insisting upon this consideration, I thought that the experiment could be explained only upon the supposition, that the powder of rosin, on its falling from the
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linen bag was actually electrified negatively; in which case it would have been easy to account for the phenomena upon the well-known principle of bodies contrarily electrified attracting each other, and repelling one another when possessed of the same kind of Electricity.

In order to try the reality of my supposition by experiments, I insulated a brass plate upon a glass stand, and connected a very sensible electrometer with it; then began shaking the powder of rosin upon it, in the same manner as I had done upon the electrophorus, and in a few seconds time had the pleasure to see the electrometer diverge with a very manifest degree of negative Electricity, answering my expectations exactly. The explanation of the ingenious Professor LICHTENBERG's experiment, now became very easy and natural; for the powder of rosin being actually electrified negatively, could not be attracted, except by those parts of the electrophorus which are in a contrary state, *i. e.* electrified positively. It is observed, that powder of rosin answers better for this experiment than

than the powders of other substances; and accordingly I find that this powder, when shaken upon the insulated brass plate, shews a stronger degree of Electricity than the other powders. Indeed the Electricity of the powder of rosin, not only when shaken upon the brass plate in the manner above-mentioned, but simply let fall upon it from a piece of paper, a spoon, &c. is very great; half an ounce of this powder being sufficient, to let the threads of the electrometer diverge as much as they possibly can.

This discovery not only affords an easy explanation of Professor LICHTENBERG'S experiment upon the electrophorus, but shews a method of exciting powders, which has long been a desideratum in the science of Electricity. The method is as follows : — Insulate a metal plate upon an electric stand, and connect with it a cork-ball electrometer; then the powder required to be tried, being held in a spoon, or other thing, at about six inches above the plate, is to be let fall gradually upon it. In this manner the Electricity acquired by the powder, being communicated to the metal plate,

plate, and to the electrometer, is rendered manifest by the divergence of the threads; and its quality may be ascertained in the usual manner. See fig. the 4th of Plate IV.

It must be observed, that if the powder is of a conducting nature, like the amalgam of metals, sand, &c. it must be held in some electric substance, as a glass phial, a plate of sealing-wax, or the like. Sometimes the spoon that holds the powder may be insulated; in which case, after the experiment, the spoon will be found possessed of an Electricity contrary to that of the powder.

In performing these experiments care must be had to render the powders, and whatever they are held in, as free from moisture as possible; sometimes it being necessary to make them very warm, otherwise the experiment is apt to fail. The following are the particulars that I have observed with this new method, which however are neither numerous, nor often repeated; but they may suffice to excite
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the curiosity of those persons, who have leisure and the opportunity of repeating them more at large and in a greater variety.

Powder of rosin, whether it be let fall from paper, glass, or a metal spoon, electrifies the plate strongly negative ; the spoon, if insulated, remaining strongly positive. Flower of sulphur produces the same effect, but in a little less degree. Pounded glass, let fall from a piece of paper, made dry and warm, electrifies the plate negatively, but not in so strong a degree as rosin. If it is let fall from a brass cup, it electrifies the plate positively, but in a very small degree.

Steel-filings let fall either from a glass phial or paper, electrify the plate negatively ; but brass-filings, treated in the same manner, electrify the plate positively. The amalgam of tin-foil and mercury, gunpowder, or very fine emery, electrify the plate negatively, when they are let fall upon it from a glass phial. Quicksilver, from
a glass

a glass phial, electrifies the plate positively.

Soot from the chimney, or the ashes of common pit-coals mixed with small cinders, electrify the plate negatively, when let fall from a piece of paper.

Description of the improved atmospherical Electrometer.

Fig. the 2d of Plate IV. is a geometrical representation of my new atmospherical electrometer, in its real size; this instrument, whose first hint I received from my friend T. RONAYNE, Esq; after various trials, I brought to the present state of perfection, as long ago as the year 1777; and immediately after, several of them were made after my pattern by Mr. ADAMS, philosophical instrument maker, in Fleet Street. The great difficulty attending the construction of this instrument, has long dissuaded my publishing any description of it; nor had I ever presented the description of it to the Royal Society, if the observations of several of my friends, who have used it, in England and abroad, joined to my own repeated experiments, had not indisputably confirm-

ed its superiority over any other instrument of that kind. Its particular advantages are : I. The smallness of the size * ; II. Its being always ready for experiments, without fear of entangling the threads, or having an equivocal result by the sluggishness of its motion ; III. Its being not disturbed by wind or rain ; IV. Its great sensibility ; and V. Its keeping the communicated Electricity longer than any other Electrometer.

The principal part of this instrument is a glass tube C D M N, cemented at the bottom into the wooden piece A B, by which part the instrument is to be held when used for the atmosphere ; and it also serves to screw the instrument into its wooden case A B O, fig. I. when it is not to be used †. The upper part of the tube C D M N, is shaped tapering to a smaller extremity, which is entirely covered with sealing-wax, melted by heat, and not dis-

* Sometime ago I made one so small, that its case which is of brass, measures only $3\frac{1}{3}$ inches in length and $\frac{9}{16}$ of an inch in diameter, and yet it acts exceeding well.

† The whole case of this electrometer has been, made also of brass, and has been found to answer better than wood, as it does not warp.

solved by spirits. Into this tapering part a small tube is cemented, the lower extremity G of which being also covered with sealing-wax, projects a short way within the tube C D M N. Into this smaller tube a wire is cemented, which with its lower extremity touches the flat piece of ivory H, fastened to the tube by means of cork: the upper extremity of the wire projects about a quarter of an inch above the tube, and screws into the brass cap E F, which cap is open at the bottom, and serves to defend the waxed part of the instrument from the rain, &c. In fig. 3. a section of this brass cap is represented, in order to shew its internal shape, and the manner in which it is screwed to the wire projecting above the tube L. The small tube L, and the upper extremity of the large tube C D M N, appear like one continued piece, on account of the sealing-wax, which covers them both. The conical corks P of this electrometer, which by their repulsion shew the Electricity, &c. are as small as they can possibly be made, and they are suspended by exceedingly fine

silver wires ; these wires are shaped in a ring at the top, by which they hang very loosely to the flat piece of ivory H, which has two holes for that purpose. By this method of suspension, which is applicable to every sort of electrometer, the friction is lessened almost to nothing, and thence the instrument is sensible of a very small degree of Electricity. I M; and K N, are two narrow slips of tin-foil, stuck to the inside of the glass C D M N, and communicating with the wooden bottom A B ;—they serve to convey off that Electricity, which, when the corks touch the glass, is communicated to it, and being accumulated, might disturb the free motion of the corks.

In regard to its use, this instrument may serve to observe the artificial, as well as the atmospherical Electricity. When it is to be used for artificial Electricity, this electrometer is set upon a table or other convenient support ; then it is electrified by touching the brass cap E F with an electrified body, which Electricity will sometimes

times be preserved for more than an hour *; in this state, if any electrified substance is brought near the cap E F, the corks of the electrometer, by their converging or diverging more, will shew the species of that body's Electricity.

Before we proceed, it is necessary to remark, that to communicate any Electricity to this electrometer, by means of an excited electric, *e. g.* a piece of sealing-wax (which we suppose as always negatively electrified) is not very readily done in the usual manner, because of the cap E F being well rounded, and free from points or sharp edges. By the approach of the wax, the electrometer will be caused to diverge; but as soon as the wax is removed, the wires immediately collapse. The best method to electrify it, is to bring the excited wax so near the cap, that one or both the corks may touch the side of the bottle C D M N; after which, they will soon collapse and appear unelectrified; if now the wax is re-

* I once made an electrometer of this sort, which could continue to be electrified for above 12 hours, and that in a room without fire.

moved, they will again diverge, and remain electrified positively.

In this operation, the wax does not impart any of its Electricity to the electrometer, but only acts by means of its atmosphere, *viz.* when the excited wax is first brought near the brass cap E F, (agreeable to the well-known law of Electricity, and according to Dr. FRANKLIN's hypothesis) it determines the electric fluid naturally belonging to the corks, towards the cap; hence the corks repel each other. Now, if in this state they touch the sides of the glass C D M N, they acquire from it a quantity of electric fluid equal to that which, by the action of the excited wax, was driven towards the cap; consequently they collapse, and appear unelectrified. Notwithstanding this appearance, the cap is actually overcharged; so that when the wax is removed, the overplus of the electric fluid, which the corks had acquired from the glass and tin-foil stuck upon it, and which was crowded upon the cap, because of the negative atmosphere of the wax, now diffuses itself equally through the cap,

the wires, the corks, &c. and therefore the corks repel each other with positive Electricity.

If, instead of the sealing-wax excited negatively, an electric possessed of positive Electricity be used, the electrometer acquires the negative Electricity, and the explanation, *mutatis mutandis*, is the same as above.

By considering this remark it will appear, that when this electrometer is electrified either positively or negatively, and an electrified body be brought towards the brass cap, the Electricity of that body will be of the same kind with that of the electrometer if the corks increase their divergency ; but it will be of the contrary kind if the corks approach one another.

When this instrument is to be used to try the Electricity of the fogs, the air, the clouds, &c. the observer is to do nothing more than to unscrew it from its case, and, holding it by the bottom A B, to present it to the open air, a little above his head, so

that he may conveniently see the corks P, which will immediately diverge if there is any sufficient quantity of Electricity; whose nature, *i. e.* whether positive or negative, may be ascertained by bringing an excited piece of sealing-wax, or other electric, towards the brass cap EF.

It is perhaps unnecessary to remark, that this observation must be made in an open place, as the roads out of town, the fields, the top of a house, &c.

In the roads between Islington and London, I have often made use of this instrument: by which I have confirmed the observations of THOMAS RONAYNE, Esq; who first discovered the Electricity of the fogs, as testified by a paper of his published in the Phil. Transactions; and who has remarked, that a fog is very rarely not electrified, but in frosty weather the air is constantly electrified.

Promiscuous Experiments.

Having had frequent occasion to observe how difficult it is to deprive sealing-wax

of its Electricity entirely, after it has been well excited, I had the curiosity to try whether water could effect it; in order to that, I tied a stick of sealing-wax to a silk string, about a yard long, and after having excited it very powerfully with flannel, I plunged it in a tin vessel full of water, and immediately drawing it out, brought a very sensible electrometer near it, and observed, that at first it shewed no sign of Electricity, but in about half a minute's time it manifested a small, but very sensible degree of negative Electricity. A glass tube treated in the same manner, was deprived of all its Electricity by the water.

I have often remarked, that after having excited a glass tube with the amalgamed rubber, in the usual manner, the part of it which had been under my hand was negative. This minus state was still more conspicuous, when I grasped with my hand the part next above, *viz.* part of that which had been excited positively by rubbing. In the same manner, when I excite a stick of sealing-wax by rubbing it with flannel, I often find, that the part of it

which I had held with my hand was in a contrary state of Electricity, *viz.* positive.

Being desirous of trying the conducting power of the effluvia of burning bodies, in a manner more satisfactory than it had hitherto been done, I contrived an instrument for that purpose, which is represented in fig. 5 *. The handle of it, A B, is a glass tube, into the extremity B of which, a wire E I, and a smaller glass tube B C, are cemented by means of sealing-wax. From the extremity of this small tube, another wire G F proceeds, which, as well as the wire E I, is bent at top, so that the extremities of both wires E F may be about one-tenth of an inch from one another. G H is a small wire, fastened to the wire F G, and to the extremity of the handle, so that when the instrument is held in one's hand, this wire touches the hand. K is a small cork-ball electrometer, which, when the instrument is to be used, is affixed to the pin D, which proceeds from the wire I E. When ex-

* This fig. is half the real size of the instrument.

periments

periments are to be tried with this instrument, the electrometer K must be affixed to the pin D, and must be electrified so as the cork-balls may diverge as far as possible: this done, the extremities E F of the wires are brought within the effluvia that are to be tried, which, if they are of a good conducting nature, will complete the communication between the two wires E F, and discharge the electrometer of its Electricity; otherwise the electrometer will remain electrified for a considerable time. The experiments which I made with this instrument are neither numerous, nor so often repeated as to be depended upon; excepting one only, which perhaps it will not be useless to mention: I found that the fumes arising by the action of a lens from the amalgam of tin-foil and mercury, conducted so badly, that the electrometer lost its Electricity in a time very little less than is required without any fumes whatever.

C H A P. VIII.

Experiments concerning the Effects of Electricity in Vacuo.

BEFORE we begin with the narration of the experiments made with a view of ascertaining the effects of Electricity in vacuo, it will be proper to mention the state of knowledge relating to electric attraction and repulsion, conducting power, and the appearance of electric light in vacuo.

The inquisitive Mr. BOYLE, towards the latter end of the last century, observed, that excited electrics would attract in the vacuum of his air-pump; in consequence of which he concluded that the presence or absence of air did not interfere with electric attraction. In the beginning of the present century Mr. GREY repeated Mr. BOYLE's experiments, and, like him, found that electrics would attract at nearly the same distance in vacuo as in air. He likewise made some other experiments in vacuo, concerning

concerning electric attraction and repulsion, from which the same deductions could be inferred. After Mr. GREY divers other ingenious persons repeated such-like experiments, and came to very nearly the same conclusion; but F. BECCARIA seems to have been the first person who asserted, that in a perfect vacuum there is no electric attraction, and his assertion is certainly true.

As for the electric light in vacuo, numerous observations concerning its diffusibility and various shades of its colours in a moderate degree of exhaustion have been made with sufficient accuracy by Mr. HAUKEBEE, Mr. du FAY, Abbé NOLLET, F. BECCARIA, and others, who likewise observed that the vacuum was a conductor of electricity; but it is related by Dr. PRIESTLEY, in his first volume of experiments and observations on different sorts of permanently electric fluids, that Mr. WALSH, assisted by Mr. de LUC, having made a double barometer, in which the quicksilver had been accurately boiled so as to expel all the air from the tube, found that the vacuum in the arched part of this double barometer

was

was not a conductor of Electricity, nor any electric light could be seen in it. This remarkable discovery was lately confirmed by some ingenious experiments of Mr. MORGAN, described in the 75th vol. of the Phil. Transf.; but my experiments, which are related in this chapter, were made not with a torricellian vacuum, but with an excellent air-pump, *viz.* that recommended in the preceding part of this work*.

EXPERIMENT I.

In a glass receiver, of six inches diameter and nine inches in height, having a brass cap, a brass wire of $\frac{2}{16}$ of an inch in diameter was fixed to its cap, and proceeding through the middle of the receiver, its lower extremity was five inches distant from the aperture of the receiver, and of course of the plate of the air-pump, when the receiver was placed upon it. A fine linen thread was fastened towards the top of the wire, and about four inches of it hanged freely along the brass wire, and almost in contact with it.

* An account of those experiments was read at the Royal Society in November 1784.

The extremity of the wire, which passing through the brass cap projected out of the receiver, was furnished with a ball. Thus prepared, the receiver was placed upon the plate of the pump, without any leather, or any thing else besides a little oil on its outside edge, which must be always understood in all the other experiments related in the course of this chapter. Then the exhaustion was commenced, and at intervals some Electricity was communicated, either by the approach of the Conductor of an electrical machine, or the knob of a charged jar, to the brass ball of the wire, in order to observe the strength of the repulsion of the thread from the wire in different degrees of rarefaction, which degrees were ascertained by the short barometrical gage. Proceeding in this manner, it was observed, that till the rarefaction did not exceed one hundred, to wit, till the air remaining within the receiver was not less than the hundredth part of the original quantity, whenever the Electricity was communicated to the brass ball, the thread first adhered to the wire, and then was repelled by it; though this repulsion became smaller and smaller, according as the exhaustion came

came nearer to the above-mentioned degree. The clinging of the thread to the wire first, was because, being dry, it required some time before it acquired a sufficient quantity of Electricity from the wire, and consequently it was not immediately repelled. When the air within the receiver was exhausted above one hundred times, the thread was not first attracted and then repelled as before, but only vibrated a little backwards and forwards, and then remained in the situation in which it stood when Electricity was not concerned. By exhausting the receiver still farther, the vibration of the thread when electrified was gradually diminished; so that when the degree of rarefaction was above five hundred, sparks and the discharge of a jar only made the thread vibrate in a manner just sensible; but this vibration, however small, did never become quite insensible, even when the receiver was exhausted to the utmost power of the pump, which was very near one thousand. After this the air was gradually admitted into the receiver, and at various intervals the ball of the brass wire was electrified, in order to observe whether the same phenomena appeared at the different degrees

degrees of exhaustion as had done before ; and they were found to agree with sufficient exactness.

EXPERIMENT II.

The brass wire within the same glass receiver was made very short, and from its extremity, a fine linen thread, six inches long, was suspended ; and upon the plate of the pump a small brass stand with a brass pillar was placed ; so that when the receiver was put upon the plate, and over the brass stand, about one inch length of the thread stood parallel to, and at various required distances from, the brass pillar *. In this disposition of the apparatus, whenever any the least quantity of Electricity was communicated to the knob of the brass wire, the thread was immediately attracted by the brass pillar, and adhered to it some time, because, being dry, it did not immediately part with the acquired Electricity. At various degrees of exhaustion, the electricity being communicated to the brass ball of the wire, it was found, that the

* This distance was altered by turning the brass wire which passed through a collar of leather in the brass cap of the receiver.

thread was always attracted by the brass pillar, though from a greater or less distance, according as a greater or less quantity of air remained within the receiver. Thus when the air was rarefied about one hundred times, the thread was attracted from about one inch; when the air was rarefied two hundred times, it was attracted from about $\frac{1}{2}$ of an inch; when the air was rarefied three hundred times, it was attracted from about $\frac{1}{3}$; and after this it was always attracted from about one twentieth, even when the air within the receiver was rarefied about one thousand times. It is remarkable, that when the air in the receiver is rarefied about three hundred times, if a jar is discharged through the vacuum, by touching its knob with the ball of the wire on the receiver, the thread is not in consequence of it attracted by the brass pillar; the reason of which seems to be, because that large quantity of Electricity opens at once a way through the vacuum, and passes through every part of it; whereas a small quantity of Electricity, even the action of a small electrical machine in the same room, at no very great distance from the apparatus,

apparatus, will cause the thread being attracted by the brass pillar.

EXPERIMENT III.

The brass stand, with the pillar, and the thread which proceeded from the wire, being removed from under the receiver, a very sensible electrometer was fastened, instead of the thread, to the extremity of the brass wire. This electrometer consisted of two very fine silver wires, each about one inch long, and having a small cone of cork at its extremity. The sensibility of such an electrometer is really surprising; for even the Electricity of a single hair excited, does sensibly affect it; and, as its suspension is almost without any friction or other impediment, it never deceives one by appearing to be electrified when in reality it is not so. With this preparation, the receiver being placed upon the plate of the air-pump, the air was gradually exhausted, and at intervals some Electricity was communicated to the ball on the outside of the receiver, either by an excited electric or by a charged jar, and it was found that the corks of the electrome-

ter were always made to diverge by it, even when the air was exhausted as much as possible. Indeed their divergency was smaller and smaller, and lasted a shorter time, according as the air was more exhausted, but it was visible to the last.

In this experiment, analogous to what has been observed in the preceding, when the air was exhausted above three hundred times, if a jar was discharged through the vacuum, or a strong spark was given to the knob on the top of the receiver, the corks of the electrometer diverged very little indeed, and but for an instant; whereas a small quantity of Electricity made them diverge more, and remain much longer in that state.

It seems deducible from those experiments, that electric attraction and repulsion take place in every degree of rarefaction, from the lowest to about one thousand, but that the power diminishes, in proportion as the air is more and more rarefied; and by following the low, we may perhaps conclude with F. BECCARIA, that there is no electric attraction nor repulsion in a perfect vacuum:

uum: though this will perhaps be impossible to be verified experimentally, because when in an exhausted receiver no attraction or repulsion is observed between bodies to which Electricity is communicated, it will be only suspected, that those bodies are not sufficiently small and light. But if we consult reason, and which alone ought to assist us when decisive experiments are not practicable, it seems likely that electric attraction and repulsion cannot take place in a perfect vacuum, by which I only mean a perfect absence of air; because either this vacuum is a Conductor or a Non-conductor of Electricity. If a Conductor, and as much nearer to perfection as it becomes more free from air, it must be a perfect Conductor at the same time that it becomes a perfect vacuum, in which case electric attraction or repulsion cannot take place amongst bodies inclosed in it; for, according to every notion we have of Electricity, those motions indicate or are the consequence of the intervening space in some measure obstructing the free passage of the electric fluid. And if the perfect vacuum is a perfect Non-conductor, then neither electric attraction nor repulsion can happen in it.

E X P E R I M E N T IV.

In my former experiments having always observed the electric light in the receiver of the air-pump, even when the air was rarefied to the utmost power of that machine, I thought proper to repeat that experiment with receivers of various sizes ; and accordingly have used receivers of above two feet in height, and some of as large a diameter as the plate of the pump could admit, which is about fourteen inches, but the light in it was always visible, only with different colours in different degrees of exhaustion, and always more diffused and at the same time less dense when the air was more rarefied, which seems to render probable, that, when the air is quite removed from any space, the electric light is no longer visible in it, as it must have been the case with the experiment of Mr. WALSH's double barometer ; for it is a maxim very well established in Electricity, that the electric light is only visible when the electric fluid, in passing from one body to another, meets with some opposition in its way ; and according to this proposition, when the air is entirely removed from a
given

given receiver, the electric fluid passing through that receiver cannot shew any light, because it meets with no opposition ; but this will not account for the receiver ever becoming a Non-conductor.

Having just mentioned, that according as the air is more and more rarefied in a receiver, so the electric light becomes gradually more faint, it will be proper to add, that the electric light is more diffused and less bright in an exhausted receiver than in air: thus, when the receiver is not exhausted, the discharge of a jar through some part of it will appear like a small globule exceedingly bright, but when the receiver is exhausted, the discharge of the same jar will fill the whole receiver with a very faint light ; whereas some persons, by seeing the whole receiver illuminated, are apt to say that the light of Electricity is rendered stronger and greater by the exhaustion.

EXPERIMENT V.

It is mentioned by Mr. NAIRNE, in the 67th vol. of the Philos. Transf. that having

put a piece of leather, just as it comes from the leather-sellers, into the receiver of an air-pump, and afterwards having rarefied the air in it one hundred and forty-eight times, the electric light appeared very faint in it; whereas, without the leather, and even when the air was much more rarefied, the light of the electric fluid, when made to pass through the receiver, was much more apparent. In consequence of this observation, I suspected that a little moisture in the receiver, or some other effluvia of substances, might perhaps prevent the appearance of the electric light in rarefied air, and with this view I began to put various substances successively into the receiver, and after rarefying the air by working the pump, some electric fluid was made to pass through the receiver.

When a piece of moist leather was put into the receiver the air could not be rarefied above one hundred times, and the electric light appeared divided into a great many branches; though at the same time another sort of faint light filled up the whole cavity of the receiver.

When a linen rag, moistened with a mixture

ture of spirit of wine and water, was put into the receiver, the pump could not exhaust above forty times, and the light of Electricity appeared divided into many branches.

A wine-glass full of olive oil placed under the receiver, prevented very little the exhaustion of the pump, the air being rarefied above four hundred times. The electric light appeared exactly as it usually does in the same degree of rarefaction when no oil is under the receiver, *viz.* a uniform faint light inclining to purple or red.

Concentrated vitriolic acid placed in a glass under the receiver, produced no particular effect. As for the other mineral acids, they were not tried, because, being volatile, they would have damaged the pump.

Dry solids, that had a considerable smell, as sulphur, aromatic woods previously made very dry, and some resins, produced no particular effect, any more than some of them prevented a very great degree of exhaustion, owing to some moisture which still adhered to them.

From these experiments it appears, first, that in the utmost rarefaction that can be effected by the best air-pump, which amounts to about one thousand, both the electric light and the electric attraction, though very weak, are still observable; but, secondly, that the attraction and repulsion of Electricity become weaker in proportion as the air is more rarefied, and in the same manner the intensity of the light is gradually diminished. Now by reasoning on this analogy we may conclude, that both the attraction and the light will cease in a perfect absence of air; but this will never account for this perfect vacuum ever becoming a Non-conductor of Electricity; for since the electric fluid is very elastic, and expands itself with more and more freedom in proportion as the resistance of the air is removed, it seems unnatural that it should be incapable of pervading a perfect vacuum: however, the fact seems to be fully ascertained by Mr. WALSH and Mr. MORGAN, and the only thing that remains to be done is to investigate the cause of so remarkable a property.

PART V.

THE PRACTICE OF MEDICAL ELECTRICITY.

CHAP. I.

General Remarks relating to Medical Electricity.

THE wonderful effects of that unknown cause generally named Electricity, soon after the discovery of the electrical machines, were applied as a remedy for various disorders incident to the human body. The first hints of this application, seem to have been suggested by observing the effects produced upon those persons that were electrified for curiosity; who being generally afraid of that extraordinary power, attributed entirely to it all those effects, which might in great measure have been attributed to fear and apprehension: such were an increased perspiration, heat, increase of pulsation, &c. The number of patients that were electrified at that time is prodigious, and the pretended cures

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effected

effected by it were wonderful indeed. Accounts of those miracles performed by Electricity, were published in various parts of Europe, together with the methods of electrifying the patients ; to which were added, such theories as, allowance being made for the infancy of Electricity at that time, would seem impossible ever to have been proposed to the public. Those theories were usually enforced by the account of experiments, which often proved false upon examination*. Indeed, if electrical machines could not be procured at present, we could hardly entertain any doubt concerning the veracity of those accounts, which had all the appearance of authenticity. But at present a much better acquaintance with the science of Electricity, than philosophers had about thirty or forty years ago, and less faith in the accounts of the generality of those persons, whose interest it is to promote the use of Electricity in medicine ; has pointed out the effects of that power upon the human body, in various circumstances, and has

* The medicated cylinders for electrical machines, are a remarkable instance of this kind. See Dr. PRIESTLEY's History of Electricity.

shewn how far we may confide in it; establishing, upon indisputable facts, that the power of Electricity is neither that admirable panacea it was considered by some fanatical and interested persons, nor so useless on application as others have asserted; but that, when properly managed, it is an harmless remedy, which sometimes instantaneously removes divers complaints, generally relieves, and often perfectly cures various disorders, some of which could not be removed by the utmost endeavours of physicians and surgeons.

When the first rumour occasioned in Europe by the accounts of pretended, and of a few real wonders, performed by means of Electricity, had in some measure subsided, many creditable and experienced physicians, who, justly considering it as their duty, had undertaken to examine the power of this new remedy, published some unsuccessful applications of Electricity in divers diseases; in which cases, they had not only prescribed the electrization, but the operation had been performed either by themselves, or under their inspection. These publications
gave

gave a new turn to the reputation of medical Electricity; and since that time, the generality of physicians and surgeons had not the least regard for its medical application; so that the practitioners of it were rather considered as fanatics and impostors. However, an attentive examination of this subject, after several trials, and after overcoming in great measure the rooted prejudice amongst physicians, began to establish anew the reputation of medical Electricity; and shewed that many applications of Electricity, published in the above-mentioned accounts, had proved unsuccessful, because the operation was not managed properly; so that it had been the abuse, and not the use of Electricity, that had proved unsuccessful, and in some cases even detrimental; for at that time, strong shocks and strong sparks were generally administered, which a long series of experiments and observations has proved to be generally useless or hurtful. Mr. LOVER, who practised medical Electricity for a long time, was, as far as I know, the first who protested against the use of strong shocks; and in an essay of his, intituled, *Subtil Medium proved*, asserts,

asserts, that the shocks to be used in medical Electricity should be very small ; by which treatment he hardly ever failed of curing, or at least relieving his patients.

Electricity, different from other physical applications, requires rather a nicety of operation than a thorough knowledge of the disease. That it is possible to apply Electricity properly, without a just knowledge of the disorder, may seem a paradox ; but it will be presently shewn, that to electrify a sound part of the body together with the diseased one, is by no means prejudicial, and that the degree of electrization must be regulated rather by the feeling of the patient, than by the species of disorder ; from whence it must follow, that the application of medical Electricity may be properly managed even with a superficial knowledge of the disorder. It must, however, be confessed, that farther experience may possibly shew much easier and more certain methods of applying it differently for different diseases ; and therefore it is more likely that medical Electricity will receive improvements in the hands of skilful physicians

physicians or surgeons, than when managed by ignorant persons, whose success is entirely trusted to chance.

The superiority of Electricity over other remedies, in many cases, may appear from considering, that medicines in general cannot always be confined to a particular part of the body, and to let them pass through other parts is often dangerous, for which reason they cannot be used; besides, after that those medicines have exerted their required power, they are with great difficulty, if at all, separated from the body. But it is of no consequence whether the power of Electricity passes through this or that other part of the body in order to come at the seat of the disease; and after having exerted its action, it is instantly dispersed: hence it appears why Electricity has often cured such obstinate disorders as have not yielded to any other treatment.

Having in the ninth Chapter of Part I. given a summary view of the theory of Electricity, I shall here only mention a few hints, which may promote the investigation

gation of the action of the electric fluid, especially relating to its chymical action; *viz.* if it adds any principle to those parts through which it passes, as an acid, an alkali, the inflammable principle, &c. — The observations relating to this point are, first, that when any part of the body has been exposed to the stream of electric fluid, it acquires a sulphurous, or rather a phosphoric smell, which it retains for a considerable time. Secondly, when the stream of electric fluid, issuing from a point, is directed towards the palate, a kind of acid taste is perceived. Now this smell and taste indicate, that the electric fluid either alters the parts of the body, upon which it excites those sensations, or that it carries along with itself some other principle, which may perhaps be separated from those substances, through which this fluid passes, previous to its impinging upon the body.—Whether those effects may be increased, diminished, or turned to any use, and also whether they are quite indifferent with respect to medical Electricity, are matters that require farther experiments and considerations; for nothing certain has been yet determined respecting them.

In

In various experiments, when the electric spark is taken in air, or other fluids, especially the tincture of certain flowers, it shews effects similar to those, which the inflammable principle, or an acid, produces upon those fluids *. These experiments have induced various persons to suppose, that the electric fluid is phlogiston, or an acid, or else a compound of both. But, considering that in those cases the action of the electric fluid as an acid, or as phlogiston, is exceedingly small; and also considering the violence with which it passes through the substance of bodies, the surface of which it generally burns or melts in a small degree; it seems more natural to suspect, that the above-mentioned effects are produced by that quantity of inflammable or acid principle, which the violent passage and escape of the electric fluid detaches from other bodies, rather than to consider the electric fluid itself to be an acid, or the inflammable principle; which seems to be very unlikely on various other accounts besides.

* See the last four experiments of the Third Part.

A book entitled *De l'électricité du Corps humain, dans l'état de santé et de maladie, par l'Abbé Bertholon*, was published a few years ago in France. In this work, the author, considering the usual Electricity of the atmosphere, imagines that the human body continually absorbs that Electricity of the air, and that this absorption is made through the pores of the skin, as well as through the lungs in the usual act of respiration; and, as the quantity of air which enters into the lungs of a man in the course of one day, is by the author estimated to about 1,152,000 cubic inches, he thence deduces, that the quantity of Electricity thus absorbed by the human body is astonishingly great. The author successively examines the influence of this absorbed Electricity upon the functions of the body, *viz.* upon muscular motion, upon the circulation of the blood, upon respiration, digestion, secretions, and even upon the morals of men. He also takes notice of the Electricity of several animals, and even mentions some qualities of the air, or of the aliments, which are proper to augment or diminish the Electricity of the human body. In the

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application of those principles to medicine, the author gives a table of diseases, arranged in species and genera, and comprehended under ten classes; which diseases, as he says, are occasioned in great measure, if not wholly, by Electricity, either positive or negative; and which may be cured by one or the other of those two electrical powers, according as the signs concomitant the disease may indicate.

The Abbé Bertholon also treats of the influence of atmospherical Electricity upon the number of births or deaths, and other things of the like nature.

A person versed in Electricity, considering that the air next to the body of a man, in his usual mode of living, is seldom if ever sensibly electrified, and also that the human body is a ready conductor of Electricity, besides many other obvious considerations, must naturally suspect that the author of the above-mentioned work has indulged his fancy perhaps too much.

C H A P. II.

Directions for the practical Application of Electricity for the Cure of various Diseases.

OMITTING the description of the electrical machine, and the manner of preserving it in good order (which things are to be found in the first part of this work) I shall only observe, with respect to the electrical machine in general, that its size should not be so small as was thought sufficient some time ago, when the smallest machines were supposed to be sufficiently useful for the purpose. It is somewhat remarkable, that when a small power of Electricity is to be used, large machines should be recommended; whereas, a short time ago, strong shocks were administered, and small electrical machines were used; but it must be considered, that when shocks are given, very small electrical machines can charge a Leyden phial much stronger than required; but when the stream is used, which has lately been found to be far more efficacious, then the small machines are

mostly useless. Probably the largest machines will not be found to afford a stream too strong for medical purposes; but the useful ones, which do not require a great labour to be put in motion, and may furnish a stream sufficiently dense, should have the glass globe or cylinder about nine inches in diameter, which, with a proportionate Conductor, may usually give sparks about three inches long. Whether the rubber of these machines stands upon a glass pillar or not, *viz.* whether it may be occasionally insulated or not, seems to be immaterial with respect to medical Electricity: but as to have it situate upon a glass pillar is useful for electrical experiments in general, and perhaps it may be found hereafter, that negative electrization is beneficial in some disorders, a person who is to choose a new electrical machine, may rather have the rubber fixed upon a glass pillar, than otherwise. Mr. NAIRN's new machine has every necessary advantage*.

With such machines, the power of Electricity should be so regulated, as to apply

* See vol. I. p. 165.

every degree of it with facility and readiness ; beginning with a stream issuing out of a metal point, next using a wooden point, then small sparks, stronger sparks, and lastly small shocks. Every one of these methods may be increased or diminished considerably, by a proper management ; thus, by turning the wheel of the machine swifter or slower, the stream of electric fluid may be regulated according as the circumstances may require. The sparks may also be made stronger or weaker, by taking them at a greater or less distance, and by turning the wheel swifter or slower ; and so of the rest.

It is impossible to prescribe the exact degree of electrization that must be used for various disorders ; for persons of different constitutions, although afflicted with the very same disease, require different degrees of electrization. Some persons are of so delicate and irritable a constitution, that the smallest sparks give them as much pain as shocks do to others. On the contrary, some people can suffer pretty severe shocks without positive pain ; and I have heard,

though never saw any, of persons who were insensible of any electric power, even of considerably strong shocks.

In respect to this important point, the operator must be certainly instructed by experience ; however, in the beginning, he may be assisted by the two following rules. First, he should begin to administer to his patients the very smallest degree of electric power, which he ought to continue for a few days, so as to observe whether it produces any good effect, which if it fails to do, he should then increase the strength of Electricity ; and so proceed gradually till he finds the effectual method, which he should follow without variation, till the patient is intirely cured. In short, the operator should always use the smallest degree of electric power, that is sufficient for the purpose. A little practice will enable him to determine at once what degree of Electricity is required for his patient, without any useless attempts. Secondly, the degree of electrization to be administered, should never exceed that, which the patient can conveniently suffer ;
experience

experience shewing, that when the application of any degree of Electricity is very disagreeable to the patients, they very seldom mend.

The instruments which, besides the electrical machine and its prime Conductor, are necessary for the administration of medical Electricity, may be reduced to three; *viz.* an electric jar, with Mr. LANE's electrometer; an insulated chair, or an insulated stool, upon which a common chair may be occasionally set; and the directors*.

Those instruments are delineated in the fifth plate. Fig. 1. represents the electric jar, with Mr. LANE's electrometer, and the manner in which the shocks are sent through any particular part of the body. The surface of the jar, which is coated with tin-foil, should be about four inches in diameter, and six inches high, which is equal to about seventy-three

* Various other instruments useful in medical electricity, are described in divers books, but those mentioned above are sufficient to answer every required purpose.

square inches. The brass wire, which passes through the covering of the jar and touches the inside coating, has a brass ball, F, to which the electrometer F D E is fastened; and proceeding a little farther up, terminates in another brass ball B, which should be so high as to touch the prime Conductor A, which is supposed to stand before the electrical machine. The electrometer consists in a glass stick F D, cemented to two brass caps F and D; from the latter of which a strong perpendicular brass wire proceeds, the extremity of which comes as high as the center of the ball B, and is furnished with an horizontal spring socket, through which the wire C E, having the brass ball C at one end, and the open ring E at the other, may be slid backwards and forwards, so as to set the brass ball C at any required distance from the ball B. This distance, at most, needs not be greater than half an inch; hence the electrometer may be made very small. Sometimes small divisions are marked upon the wire C E, which serve to set the balls B and C at a given distance from one another, with more readiness and precision. Now suppose

pose that the jar is set contiguous to the prime Conductor, that is, with the ball B touching the Conductor; that the ball C be set at one tenth of an inch distance from the ball B; and that, by means of wire, a conducting communication be formed from E to the outside coating of the jar, as is represented by the dotted line in the figure. In this case, if the electrical machine be put in motion, the jar will be charged; and when the charge is so high as that the electric fluid accumulated within the jar can leap from the ball B to C, which we have supposed to be one tenth of an inch asunder, the discharge will happen, a spark appearing between the said balls, and the shock passes through the wire represented by the dotted line; for the part F D of the electrometer being of glass, generally covered with sealing-wax, is impervious to Electricity, consequently the electric fluid has no other way through which it can pass from the inside to the outside of the glass jar. When the shocks are to be given with this apparatus to any particular part of the body, for instance, to the arm, then, instead of the dotted line representing a wire, which must

now

now be supposed as not existing in the figure, two slender and pliable wires, E L, I L, are to be fastened, one to the open ring E of the electrometer, and the other to the brass hook I of the stand H I, which communicates with the outside coating of the jar *. The other extremities of the said wires are fastened each to the brass wire L, and L, of the directors K L, K L. Each of those instruments, justly called *directors*, consists of a knobbed brass wire L, which by means of a brass cap is cemented to the glass handle K. The operator, holding them by the extremity of the glass handle, brings their balls into contact with the extremities of that part of the body of the patient through which he desires to send the shock. The management and convenience of this apparatus are easily comprehended by inspecting the figure; for when the machine is in motion, and the apparatus, &c. is situate as in the figure, the discharge of the jar must be

* If the jar has not the stand H I, the extremity I of the wire I L may be simply rested under, or may be tied round it. In short, it must be put in contact with the outside coating of the jar, in any convenient manner.

evidently

evidently made through that part of the patient's arm, which lies between the knobs of the directors; and the operator, whilst an assistant keeps the machine in motion, has nothing more to do, than to hold the knobs of the directors to the extremities of the arm, or to any other part of the body that is required to be thus electrified; always taking care that the two wires E L, I L, do not touch each other, because in that case the shock will not pass through that part of the body which is required to be electrified. Thus any number of shocks, precisely of the same strength, may be given, without altering any part of the apparatus, or having any farther trouble; and when the strength of the shocks is required to be diminished or increased, it is only necessary to diminish or augment the distance between the balls B C, which is done by slipping the wire C E forwards or backwards through the spring socket that holds it.

It is almost superfluous to mention, that when shocks are administered, it is immaterial whether the patient stands upon the ground,

ground, upon the insulating stool, or in any other situation whatever. It is neither always necessary to remove the cloaths from the part that must be electrified, in order to let the knobs of the directors touch the skin; for, except the coverings be too many and too thick, in which case part of them at least should be removed, the shocks will go through them very easily, especially if the knobs of the directors be pressed a little upon the part.

In the course of this essay we shall describe the strength of the shocks by the distance between the balls B and C of the electrometer, which we shall express by parts of an inch; supposing that the said electrometer is fixed upon such a jar as we have described above, *viz.* whose coated part, besides the bottom, may be equal to about 73 square inches, and whose glass is moderately thin; for a larger or thicker jar with the same electrometer, set at the same distances, will produce a much different effect, as must be obvious to any person a little acquainted with the science of Electricity.

Besides

Besides the directors mentioned above, there are other kinds of directors, which serve for throwing the stream of electric fluid, and other similar purposes. These are delineated in fig. 2. and 3. The director D, in fig. 2. is much like those described above, excepting only that its wire is bent, and instead of having any ball, it terminates in a point, to which is affixed a piece of wood about one inch or one inch and a half long, pointed on one end, though not very sharp, and having a hole on the other *. The operator should have by him various such wooden pieces, of different length and thickness, as E E, so as to shift them according as circumstances may require ; for sometimes the wooden pieces are too dry or too damp, or the machine is in bad order, &c. in which cases the stream of electric fluid would be either too strong or too weak, if the same wooden point was always used. The wood proper to make these pointed pieces should be rather of a soft kind, than hard, as box wood and *lignum vitæ* are.

* These directors are sometimes made with very slender and annealed wires, so that they may be bended in every required direction.

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In order to throw the electric fluid with this director, let a wire B, proceeding from the prime Conductor A, fig. 2. be fastened to the wire of the director DE, which the operator must hold by the extremity of the glass handle, and must manage it so as to keep the wooden point at about one or two inches distance from the body of the patient*. This distance, however, must be regulated according to the constitution of the patient, the strength of the electrical machine, and other circumstances, which will be suggested by a little practice. The electric fluid issuing from the wooden point, has a power which is intermediate between that of the stream proceeding from a metal point, and the power of the sparks; but yet it is in general the most efficacious method of electrization, and therefore no pains should be spared in order to administer it in the best possible manner. This stream consists of a vast number of exceedingly small sparks, accompanied with a little

* When this or any other operation is performed, the electric jar, and in general any instrument not actually necessary, must be removed from the prime Conductor, and even from the table if that is rather small.

wind,

wind, which gently irritates the part electrified, and gives a warmth which proves very agreeable to the patients. Sometimes, when the machine is very powerful, and the wooden point is short or split, a very full and pungent spark issues from it; which is a very disagreeable accident, especially when the part electrified is very delicate. In order to avoid this inconvenience, the operator should first try the goodness of the point, before he begins the operation; which he may do by throwing the stream upon his own hand or face.

The above-mentioned method of electrifying, gentle as it may appear, will nevertheless be found too strong for some persons, especially when used for open sores upon delicate parts; in which cases the wooden point must be removed, and the electric fluid must be simply thrown from the metal point of the director, which must now be kept at a greater distance than when the wooden piece was upon it. The electric fluid issuing out of this pointed wire of the director, occasions only a gentle wind upon the part towards which it

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is

is directed, and is far from being disagreeable even to the most delicate constitution.

It might be naturally suspected, that so gentle and nearly insensible a treatment could hardly be of any efficacy; but my reader may be assured, that to my certain knowledge, deduced from the practice of persons who have had long experience in this subject, this method of electrization, *viz.* the throwing the fluid with a metal point, has often mitigated pains, and cured obstinate and dangerous diseases, which could not be removed by any other remedy that was tried.

In general this treatment, upon delicate nervous constitutions, is as efficacious as the other, *viz.* the throwing the fluid with a wooden point, is to ordinary constitutions. In several cases, especially of open sores, the electric fluid issuing out of a wooden point has constantly increased the pain, and even enlarged the sore; whereas the fluid issuing out of the metal point has effectually diminished both.

The stream issuing out of a wooden point may be directed towards the eyes of the patient, without any apprehension of hurting him; in which case the operator should keep the eye-lid open with one hand. Indeed there might be some cases, though I seldom heard of any, in which this treatment may be thought to be too strong; then the metal point only may be used.

The stream issuing both out of the wooden and of the metal point, acts even through the cloaths, if they are not too thick; hence it may be used without incommoding the patient; but when it is convenient to uncover the part that is to be electrified, it is much preferable to direct the fluid immediately upon the skin.

In this operation, the practitioner must mind to shift the point of the director about, so that the stream of electric fluid may be directed not only towards the affected part, but also to the places about it; alternately returning to the same place, and mostly insisting upon the part principally affected.

The patient in this operation may also stand in every situation that may happen to be more convenient to him.

When more proper instruments cannot be had, directors may be made by sticking large pins upon sticks of sealing-wax, as is represented at K, fig. 2.

Sometimes the wire B, which forms the communication between the prime Conductor and the director, throws a considerable quantity of electric fluid into the air, which weakens the stream issuing from the point. In order to remedy this inconvenience, I contrived a conducting wire, which being used by some of my friends, who practise Medical Electricity, has been found to answer very well the purpose of not dissipating the electric fluid. This conducting communication is formed of a silver, gold, or copper thread, such as are used for laces, which consist of a small lamina of metal twisted round a silk or linen thread. This metal thread, or two of them, I involve in a silk ribbon, which is coiled and sewed very tight upon it, leaving only a loop of the
metallic

metallic thread uncovered at each extremity, one of which is to be fastened to the prime conductor, and the other to the wire of the director. See G H, fig. 2.

This sort of conducting communication, besides its preventing the dissipation of the electric fluid, is much more pliable than the stiff wire commonly used, and consequently may be managed more easily. It may be also used instead of the wires C L, I L, fig. 1. in the operation of giving shocks.

Two other directors different from the above-mentioned, are delineated in fig. 3. Their use is to draw sparks from the inside of the ear in cases of deafness, pains, &c. and also from the teeth or other internal parts of the mouth. The director B H consists of a glass tube A B, about six inches long, and open at both ends; the diameter of which may be about one tenth of an inch, and the substance of the glass rather thick. A cork is thrust into one end of this tube, through which a wire passes; one extremity of which is cut blunt and smooth,

and comes within one or two tenths of an inch shorter than the end B of the tube. The other extremity H of the wire, is furnished with a small metal ball.—Long pins, such as the ladies use for their hats answer this purpose exceedingly well, when their points are filed off. The other director CD differs from that just described, in being only bent a little, for the convenience of adapting it more easily to some parts within the mouth.

When these directors are used, the patient must be situated upon an insulating stool, *viz.* a stool furnished with glass feet, upon which a chair may be placed. Then a communication must be formed between the prime Conductor and the body of the patient, by means of any sort of wire, especially that represented by GH, fig. 2. or by the patient only touching the prime Conductor with his hand. In this case, it is easy to conceive that the patient becomes part of the prime Conductor; and if any blunt conducting body is brought near him, when the machine is in action, a spark is obtained from him in the same manner

manner as when the same blunt body is presented to the prime Conductor itself. Every thing being thus far prepared, the operator holding the director A B or C D by its middle E or F with one of his hands, must bring the extremity B or D of the tube into contact, or nearly so, with the inside of the ear, mouth, &c. of the patient, as occasion may require ; and must bring the knuckle of a finger of his other hand within a small distance of the small knob H or G of the director, which will extract small sparks from it, and at the same time the like sparks will happen between the other extremity of the wire within the tube, and the part of the patient's body towards which the instrument is directed.

This is an excellent method to be practised in cases of deafnesses, pains in the ears, tooth-achs, swellings within the mouth, &c. especially because it may be increased or diminished at pleasure ; *viz.* by drawing the wire G or H more or less from the extremity B or D of the tube, the strength of the sparks may be increased or diminished.

Not only sparks, but also the stream of electric fluid may be drawn with those directors. This is done by bringing (instead of the knuckle) a pointed piece of wood near the small knob H or G of the director; every thing else being disposed as already directed.

When sparks are required to be drawn from any part of the body, the patient must be situated upon an insulating stool, and must be connected with the prime Conductor in the manner directed above; then the operator bringing the knuckle of one of his fingers, or the knob of a brass wire like K L, fig. 3. opposite to the affected part, will draw the sparks from it; which sparks will pass very easily through the cloaths, if they are not very thick. When the knobbed wire K L is used to draw sparks with, the operator must hold it by the extremity K, and present the knob L, &c. : but it may also be used to draw the fluid silently, in which case the point K must be presented, and the knob L must be held by the hand of the operator. Here a wooden point may also be
used,

used, *viz.* by affixing it to the point K of the wire ; which method answers as well as that of throwing the electric fluid by means of a wooden or metal point, with the director D of fig. 2. described in the preceding pages.

Sometimes it is required to take sparks from such parts as are covered with thick cloaths, and the patient is rather unwilling to uncover. In this case the best method is to situate the patient upon the insulating stool in contact with the prime Conductor, then to bring the knob of a director, like one of those delineated in fig. 1. in contact with the cloaths over the part required to be electrified ; whilst the operator, holding the instrument by the extremity of its glass handle with one of his hands, brings the knuckle of one of his fingers, or the knob of the wire K L, fig. 3. pretty near the brass cap of the director, so as to draw strong sparks from it ; the force of which will be felt very smartly upon the part of the patient's body ; for at the same time sparks will happen there across the cloaths, *viz.* between the part of the body of the

K 4
patient,

patient, and the knob of the director, which, for better security, should be pressed a little upon the cloaths.

In all those cases when the electric fluid, either in a stream or under the form of sparks and shocks, is to be forced across the cloaths, it is supposed that no metallic ornaments should be interposed, as gold or silver lace, long pins, and the like; for then the effects will vary considerably, according to the different circumstances.

There is another method of electrifying a diseased part of the body, which cannot properly be called drawing sparks, though it comes very near to it. This manner of electrifying is effected in the following way: The patient is situated upon the insulating stool, and is made to communicate with the prime Conductor; then a dry and warm flannel, either single or double, according as it may be occasionally thought more proper, is spread upon the naked part that must be electrified, and over this flannel the operator must put the knob L of the wire K L, fig. 3. quite into contact

tact with the flannel, whilst he holds it by the other extremity K. Now when the machine is in action, the knob L of the wire must be shifted very quick and nimbly from place to place over the flannel; in which manner a vast number of exceedingly small sparks will be drawn across the flannel; which generally bring an agreeable warmth on the part, and prove very beneficial to the patient, at the same time that they do not cause any very disagreeable sensation. In cases of paralytic limbs, rheumatism, spreading pains, coldness of any particular part, &c. this treatment is of singular benefit. In the following pages we shall call it *The method of drawing sparks through a piece of flannel*, or simply, *to draw sparks through flannel*.

As for the insulating chair, it is almost needless to give any particular directions concerning its construction; it being nothing more than a common wooden chair set upon an insulating stool; or, as some persons choose to have it, the chair itself is furnished with glass instead of wooden legs, which answers equally well. It is
requisite

requisite that no sharp metallic points be put upon this chair; and even its wooden ornaments should be rather blunt than sharp-edged; for points and edges in general dissipate the electric fluid considerably, and consequently weaken the power of the machine. The glass feet should be at least eight inches high; and, that they may insulate the better, especially in damp weather, they should be covered with sealing-wax or good amber varnish. In the construction of this chair, a place should be always provided, whereupon the patient may rest his feet; the want of which is very disagreeable, because it is absolutely necessary that the feet do not touch the floor.—When only a common chair is to be occasionally set upon an insulating stool, the latter should be made somewhat larger than the former, so that part of it may project before the chair, upon which the person to be electrified may rest his feet.

After the description of the instruments necessary for the administration of Medical Electricity, I shall collect together some practical rules, which may serve for a guide

to those practitioners, who have not yet been sufficiently instructed by their own experience.

General Rules for Practice.

I. It should be attentively observed, to employ the smallest force of Electricity, that is sufficient to remove or to alleviate any disorder ; thus the shocks should never be used when the cure may be effected by sparks ; the sparks should be avoided when the required effect can be obtained by only drawing the fluid with a wooden point ; and even this last treatment ought to be omitted, when the fluid drawn by means of a metal point, may be thought sufficient. The difficulty consists in distinguishing the proper strength of electric power that is required for a given disorder, the sex and constitution of the patient being considered. In regard to this point, it is impossible to give any exact and invariable rules ; the circumstances being of such a nature, and so various, that long experience, and a strict attention to every particular phenomenon, are the only means by

by which proper instructions may be received. The surest rule, as we observed above, that can be given relating to this particular, is to begin by the most gentle treatment; at least such, that, considering the constitution of the patient, may be thought rather weak than strong. When this gentle treatment has been found ineffectual for a few days, which is denoted by the disease not abating, and the application of Electricity not causing any warmth, or other promising phenomenon, upon the part electrized; then the operator may gradually increase the force of Electricity till he finds the proper degree of it.

II. In judging of cases proper to be electrified, experience shows, that in general, all kinds of obstructions, whether of motion, of circulation, or of secretion, are very often removed or alleviated by Electricity. The same may also be said of nervous disorders; both which include a great variety of diseases. The application of Electricity has seldom intirely cured diseases of a long standing, although it generally relieves them. To persons afflicted with
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the venereal disease, or to pregnant women, electrization has been thought to be pernicious ; but my reader may be assured, that even in those cases it may be used without fear, if it is judiciously managed. When pregnant women are to be electrified for any disorder, the shocks should be absolutely forbidden ; and even when the other more gentle treatments are used, a constant attention should be given to any phenomenon that may appear in the course of the electrization ; the method of which should be increased, diminished, or suspended, according as circumstances may indicate. As for the venereal disease, it will be hinted, in the course of this work, in what manner, and in which cases, Electricity may be applied.

III. In cases of gathering tumours, the best method is to draw the fluid by means of a wooden point, or, if that proves painful, by a metal point. Sparks in these cases, and also shocks, are often hurtful. In stiffnesses, paralyties, and rheumatism, small sparks, especially through a double flannel, and also very small shocks (at most of one
tenth

tenth of an inch) may be used. Stronger shocks may be sometimes, though seldom, administered for a violent tooth-ach, and for some internal spasm of no long standing.

IV. When any limb of the body is deprived of motion, it must be observed, that the privation of motion is not always originated by a contraction of the muscles; but that it is often occasioned by a relaxation; thus, for instance, if the hand is bent inwardly, and the patient has no power of straightening it, the cause of it may be a weakness of the outward muscles, as well as a contraction of the inward ones. In such cases, as it is often difficult even for good anatomists to discover the real cause, the surest method is to electrify not only those muscles which are supposed to be contracted, but also their antagonists; for to electrify a sound muscle is by no means hurtful.

V. When the stream of electric fluid is thrown either with a wooden or metal point, the length of the operation should be from three to ten minutes: more or
 2 less,

less, according as occasion may require. When shocks are administered, their greatest number should not exceed a dozen or fourteen, except when they are to be given to the whole body in different directions. The number of sparks, when they are used, may generally exceed the number of shocks mentioned above.

VI. Lastly, it may be of use to mention, that when children must be electrified upon the insulating chair, as it is difficult to let them stay without motion, the most convenient method is, to let another person sit in the insulating chair, and to hold the child whilst the operator is electrifying him.

Having thus comprised into a few general rules, the method of applying Electricity with safety, we shall next describe the particular treatment, which has been found more expeditious and beneficial in disorders of various species ; and shall lastly add some authentic cases, which will serve as examples for the generality of practitioners.

The minute detail of the apparatus necessary

cessary for Medical Electricity, and several of the observations made on the particular use of it, may be thought more than necessary for a person who is master of the preceding part of this work; but as it is more than probable, that many persons will consult this book merely for the sake of the medical part, I thought proper to prevent any possible mistake, or insufficient instruction, which might arise from conciseness.

C H A P. III.

Containing the particular Method of administering Electricity for various Diseases, and the Account of some authentic Cases.

THE account of a few successful cases in Medical Electricity, as well as in any other branch of physic, does by no means establish the reputation of the treatment, when a vast number of unsuccessful trials are concealed from the eyes of the public. The variety of temperaments observable in the human species, and the coincidence of circumstances, is such, that sometimes very obstinate disorders seem to be cured by very trifling applications. The
physicians,

physicians, however, justly neglect those kinds of treatment, because they have actually failed in a great many cases seemingly of the same nature.

In order, therefore, to give a proper estimate of the efficacy of a remedy, it is necessary to shew the proportion between the successful, and the unsuccessful trials; without being amazed at one case, and neglecting many others.

Agreeably to this observation, the reader will find in the following pages, an estimate of the effects of Electricity applied as a remedy for various disorders. This estimate has been deduced from the cases which are hitherto come to my notice, and is therefore likely to receive much alteration and amendment by better information, and future observations.

Rheumatic disorders, even of long standing, are relieved, and generally quite cured, by only drawing the electric fluid with a wooden point from the part, or by drawing sparks through flannel. The operation should be continued for about four

or five minutes, repeating it once or twice every day.

Deafness, except when it is occasioned by obliteration, or other improper configuration of the parts, is either intirely or partly cured by drawing the sparks from the ear with the glass-tube-director, or by drawing the fluid with a wooden point. Sometimes it is not improper to send exceedingly small shocks (for instance, of one-thirtieth of an inch) from one ear to the other.—It has been constantly observed, that whenever the ear is electrified, the discharge of the wax is considerably promoted.

The tooth-ach, occasioned by cold, rheumatism, or inflammation, is generally relieved by drawing the electric fluid with a point, immediately from the part, and also externally from the face. But when the body of the tooth is affected, electrization is of no use; for it seldom or never relieves the disorder, and sometimes increases the pain to a prodigious degree.

Swellings in general, which do not contain any matter, are mostly cured by
drawing

drawing the electric fluid with a wooden point*. The operation should be continued for three or four minutes every day.

Inflammations of every sort are generally relieved by a very gentle electrization.

In inflammations of the eyes, the throwing of the electric fluid by means of a wooden point, is constantly attended with great benefit; the pain being quickly abated, and the inflammation being generally dissipated in a few days. In these cases, the eye of the patient must be kept open, and care should be taken not to bring the wooden point very near it. Sometimes it is sufficient to throw the fluid with a metal point; for in these cases, too great an irritation should be always avoided. It is not necessary to continue this operation for three or four minutes without intermission; but, after throwing the fluid for about half a minute, a short time may be allowed to the patient to rest, and to wipe

* It is very remarkable, that in some cases of white swellings, quite cured by means of Electricity, even the bones and cartilages were in some measure disfigured.

his tears, which generally flow very copiously; then the operation may be continued again for another half minute, and so on for four or five times every day.

The *gutta serena* has been often cured by electrization; but at the same time it must be confessed, that to my certain knowledge, Electricity has proved ineffectual in many such cases, in which it was administered for a long time, and with all possible attention. I do not know that ever any body was worsted by it. The best method of administering Electricity in such cases, is first to draw the electric fluid with a wooden point for a short time, and then to send about half a dozen shocks of one-twentieth of an inch from the back and lower part of the head to the forehead, very little above the eye.

A remarkable disease of the eyes was some time ago perfectly cured by electrization; it was an opacity of the vitreous humour. This seems to be the only case of the kind, to which Electricity was applied.

All the cafes of *fiftula lacrymalis*, as far as I am informed, that have been electrified by persons of ability for a fufficient time, have been entirely cured. The method generally practifed, has been that of drawing the fluid with a wooden point, and to take very fmall sparks from the part. The operation may be continued for about three or four minutes every day. It is remarkable that in thofe cafes, after curing the *fiftula lacrymalis*, no other difeafe was occafioned by it, as blindnefs, inflammations, &c. by fuppreffing that difcharge.

Palfies are feldom perfectly cured by means of Electricity, efpecially when they are of long ftanding and the intellect is affected ; but they are generally relieved to a certain degree. The method of electrifying in thofe cafes, is to draw the fluid with the wooden point, and to draw sparks through flannel, or through the ufual coverings of the part, if they are not too thick. The operation may be continued for about five minutes *per* day.

Ulcers, or open fores of every kind, even
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of a long standing, are generally disposed to heal by electrization. The general effects are a diminution of the inflammation, and at first a promotion of the discharge of properly formed matter; which discharge gradually lessens, according as the limits of the sore contract, till it is quite cured. In these cases the gentlest electrization must be used, in order to avoid too great an irritation, which is generally hurtful. To draw or throw the fluid with a wooden or even with a metal point, for three or four minutes *per* day, is quite sufficient.

Cutaneous eruptions have been successfully treated with electrization; but in these cases it must be observed, that if the wooden point is kept too near the skin, so as to cause any considerable irritation, the eruption will sometimes be caused to spread more; but if the point be kept at about six inches distance, or farther, if the electrical machine is very powerful, the eruptions will be gradually diminished, till they are quite cured. In this kind of disease, the immediate and general effect of the wooden point, is to occasion a warmth about the electrified

electrified part, which is always a sign that the electrization is rightly administered.

The application of Electricity has perfectly cured various cases of *St. Vitus's Dance*, or of that disease which is commonly called so; for it is the opinion of some very learned physicians, that the real disease called *St. Vitus's Dance*, which formerly was more frequent than it is at present, is different from that which now goes under that name. In this disease, shocks of about one-tenth of an inch may be sent through the body in various directions, and also sparks may be taken. But if this treatment proves very disagreeable to the patient, then the shocks must be lessened, and even omitted; instead of which, some other more gentle applications must be substituted.

Scrophulous tumors, when they are just beginning, are generally cured by drawing the electric fluid with a wooden or metal point from the part. This is one of those kinds of diseases in which the action of Electricity requires particularly the aid of

other medicines, in order to effect a cure more easily ; for scrophulous affections generally accompany a great laxity of the habit, and a general cachexy, which must be obviated by proper remedies.

In *cancers*, the pains only are mostly alleviated by drawing the electric fluid with a wooden or metal point. I know of one case only, in which a most confirmed cancer of very long standing, on the breast of a lady, has been much reduced in size. It is remarkable, that this patient was so far relieved by drawing the fluid with a metal point from the part, that the excruciating pains she had suffered for many years, did almost intirely disappear ; and also, that when the electric fluid was drawn by means of a wooden point, the pains did rather increase. This person, when I heard of her last, was still under the application of Electricity ; and the cancer seemed not unlikely to be perfectly cured, although contrary to the expectations even of the judicious physician who electrified her, and who knows too well the nature of that dangerous disease.

Abscesses,

Abscesses, when they are in their beginning, and in general whenever there is any tendency to form matter, electrization disperses them. Lately, in a case in which matter was formed upon the hip, called the *lumber abscess*, the disease was perfectly cured by means of Electricity. The *sciatica* has also been often cured by it. In all such cases, the electric fluid must be sent through the part by means of two directors applied to opposite parts, and in immediate contact either with the skin, or with the coverings, when these are very thin. It is very remarkable, that the mere passage of the electric fluid in this manner, is generally felt by the patients afflicted with those disorders, nearly as much as a small shock is felt by a person in good health. Sometimes a few shocks have been also given, but it seems more proper to omit them; because sometimes, instead of dispersing, they rather accelerate the formation of matter.

In cases of *pulmonary inflammations*, when they are in the beginning, electrization has sometimes been beneficial; but in confirmed diseases of the lungs, I do not know
that

that it ever afforded any unquestionable benefit ; however, it seems that in such cases the power of Electricity has been but seldom tried.

Nervous head-achs, even of a long standing, are generally cured by electrization. For this disease, the electric fluid must be thrown with a wooden, and sometimes even with a metal point, all round the head successively. Sometimes exceedingly small shocks have been administered ; but these can seldom be used, because the nerves of persons subject to this disease are so very irritable, that the shocks, the sparks, and sometimes even the throwing the electric fluid with a wooden point kept very near the head, throws them into convulsions.

The application of Electricity has often been found beneficial in the *dropsy*, when just beginning, or rather in the tendency to a dropsy ; but it has never been of any use in advanced dropsies. In such cases, the electric fluid is sent through the part, in various directions, by means of two directors, and sparks are also drawn across
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the flannel or the cloaths ; keeping the metal rod in contact with them, and shifting it continually from place to place. This operation should be continued at least ten minutes, and should be repeated once or twice a day.—Perhaps in those cases, a simple electrization, (*viz.* to insulate the patient, and to connect it with the prime Conductor whilst the machine is in action) continued for a considerable time, as an hour or two, would be more beneficial.

The *gout*, extraordinary as it may appear, has certainly been cured by means of Electricity, in various instances. The pain has been generally mitigated, and sometimes the disease has been removed so well as not to return again. In those cases, the electric fluid has been thrown by means of a wooden point, although sometimes, when the pain was too great, a metal point only has been used.

Agues very seldom fail of being cured by Electricity, so that sometimes one electrization, or two, have been sufficient. The most effectual and sure method has been
that

that of drawing sparks through flannel, or the cloaths, for about ten minutes, or a quarter of an hour. The patients may be electrified either at the time of the fit, or a short while before the time in which it is expected.

The suppression of the ordinary periodical fluxes of women, which is a disease that often occasions the most disagreeable and alarming symptoms, is successfully and speedily cured by means of Electricity, even when the disease is of long standing, and after the most powerful medicines used for it have proved ineffectual. The cases of this sort, in which electrization has proved useless, are so few, and the successful ones so numerous, that the application of Electricity for this disease may be justly considered as an efficacious and pretty certain remedy. Great attention and knowledge is required, in order to distinguish the arrest of the periodical fluxes from a state of pregnancy. In the former, the application of Electricity, as we observed above, is very beneficial; whereas in the latter, it may be attended with very disagreeable effects; it is therefore a matter
of

of great importance to ascertain the real cause of the disease, before the Electricity be applied in those cases. Pregnant women may be electrified for other diseases, but always using very gentle means, and directing the electric fluid through other parts of the body, distant from those subservient to generation. In the real suppression of the usual discharges, small shocks, *i. e.* of about one-twentieth of an inch, may be sent through the pelvis; sparks may be taken through the cloaths from the parts adjacent to the seat of the disease; and also the electric fluid may be transmitted by applying the metallic or wooden extremities of two directors to the hips, in contact with the cloaths; part of which may be removed in case they are too thick. Those various applications of Electricity should be regulated according to the constitution of the patient. The number of shocks may be about twelve or fourteen. The other applications may be continued for two or three minutes; repeating the operation every day. But either strong shocks or a stronger application of Electricity, than the patient can conveniently bear,

bear, should be carefully avoided ; for by those means, sometimes more than a sufficient discharge is occasioned, which is not easily cured, In cases of uterine hæmorrhages, I don't know that the application of Electricity was ever beneficial, neither that it has been often tried.—Perhaps a very gentle electrization, as to keep the patient insulated and connected with the prime Conductor, whilst the electrical machine is in action, may be of some benefit.

In respect to *unnatural discharges* and *fluxes* in general, it may be observed, that some discharges are quite unnatural or adventitious, as the fistula lacrymalis, and some species of the venereal disease ; but others are only increased natural discharges, such as the menses, perspiration, &c. Now the power of Electricity, in general, has been found more beneficial for the first, than for the second sort of discharges, which are mostly increased by it.

In the *venereal disease* electrization has been generally forbidden ; having mostly increased the pains, and other symptoms,
rather

rather than diminished them. Indeed, considering that any sort of stimulus has been found hurtful to persons afflicted with that disorder, it is no wonder that Electricity has produced some bad effects, especially in the manner it was administered some time ago, *viz.* by giving strong shocks. However, it has been lately observed, that a very gentle application of Electricity, as drawing the fluid by means of a wooden or metal point, is peculiarly beneficial in various cases of this kind, even when the disease has been of long standing. Having remarked above, that tumors, when just beginning, are dispersed, and that unnatural discharges are gradually suppressed by a judicious electrization; it is superfluous to describe particularly those states of the venereal disease in which Electricity may be applied; it is only necessary to remind the operator to avoid any considerable stimulus in cases of this sort.

The application of Electricity has been found also beneficial in other diseases besides those mentioned above; but as the

facts are not sufficiently numerous, so as to afford the deduction of any general rules, I have not thought proper to take any particular notice of them; especially, because the effects of Electricity on the human body, in various circumstances, have been already sufficiently considered under general and comprehensive heads.

We may lastly observe, that in many cases, the help of other remedies to be prescribed by the gentlemen of the faculty, is required to assist the action of Electricity, which by itself would perhaps be useless; and on the other hand, electrization may often be applied to assist the action of other remedies, as of sudorifics, strengthening medicines, &c.

“ While I was writing some of the
 “ above cases,” says Mr. BECKET, “ an
 “ observation or two occurred to me, which,
 “ though perhaps of no great consequence,
 “ may not be amiss to mention, as every
 “ particular effect of Electricity seems to
 “ be worthy of notice.

“ One

“ One circumstance attending some of
 “ the preceding cures, particularly that
 “ of the *paralytic*, related by Mr. JONES,
 “ was a fresh and copious discharge of the
 “ *blisters*, which had been previously ap-
 “ plied to the patients.—This, I think,
 “ seems to be a pretty general consequence
 “ of electrification ; at least, I have myself
 “ known many instances of it ; particu-
 “ larly in one gentleman, whom I elec-
 “ trified for a paralytic complaint, and
 “ who had a blister applied to the back
 “ part of his neck. He informed me,
 “ that, in the night after his being elec-
 “ trified the preceding day, he found a
 “ much more copious discharge from the
 “ blister than at other times ; though the
 “ operation was no more than his stand-
 “ ing, for about a quarter of an hour, on
 “ the insulated stool, while sparks were
 “ drawn from the side of his face. From
 “ hence it appears not impossible, that, in
 “ some cases, blisters may be attended with
 “ peculiar benefit, during a course of elec-
 “ trical treatment ; in others, perhaps, it
 “ might be worth while to make use of
 “ Electricity, merely to obtain a favourable
 “ discharge from the blisters.”

*Authentic physical Cases, in which Electricity was administered.**C A S E I.*

The particulars of the following case were communicated to me by Mr. PARTINGTON.

DANIEL WYSCOYL, aged thirty-six, of a strong robust constitution, was sent from the Westminster Dispensary, in Gerard-street, to Mr. PARTINGTON, in order to be electrified for a violent inflammation in both his eyes. The account he gave of his disorder, was the following:—Several dark objects of different shapes and sizes, seemed at first to obstruct his sight. This was succeeded by an inflammation in both his eyes, which increased with such rapidity, that in a week's time he was brought to the degree of blindness that afflicted him till he was electrified. He was immediately recommended to the Westminster Dispensary, where every possible attention was paid to his misfortune by Mr.

Mr. FORD, the surgeon of that place ; but the obstinacy of the disorder was such, that every endeavour made towards the relief of this poor man proved useless.— Blisters and leeches, besides the other usual means, were applied without any efficacy whatever.

About two months after the commencement of the inflammation, Mr. FORD recommended him to Mr. PARTINGTON ; who, on examining him, found that the eye-lids could not be opened without the help of the fingers, and that when opened, the coats of the eye appeared of an uniform red colour. The sight of the right eye, which was the most affected, was so far impaired, that when it was turned towards a window, the eye-lids being forced open, he could perceive only a red glare of light like a ball of fire ; but the rest of the room seemed to be equally dark, so that he could not distinguish any object in it. With the left eye he could distinguish colours, and the shapes of objects that were held to him, but in their sizes he was commonly mistaken. This disorder was accompanied with excruciating

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pains,

pains, shifting from one part to the other, but principally insisting on his temples, and sometimes darting to the back part of his head, or to the centre of his eyes.

Mr. PARTINGTON began to electrify him the 21st of October, 1776 ; and three days after the inflammation began visibly to abate, and in a fortnight's time it was quite subsided ; but the pupil of the eye was so nearly closed, that scarce any of it could be seen. He continued to be electrified every day for five weeks, and the pupil gradually dilated, till he attained a degree of sight sufficient to distinguish objects on the other side of the way. The pain had now entirely left him, so that he omitted the use of Electricity, and did not experience any farther inconvenience after it.

This remarkable cure was effected by throwing the stream of electric fluid with a metal, and with a wooden point. The first instrument used, which was contrived by the late Mr. FERGUSON, consisted in a pointed brass wire, fastened by means of a cork

a cork at the smaller end of a conical glass, open at both ends, and passing through the axis of this conical or funnel-like glass, its point came within about half an inch of the larger aperture of the glass. This instrument being designed to throw the electric fluid upon the eye, was to be fixed so that the larger aperture of the glass surrounding the eye kept its lids open, and the point of the wire was opposite to the pupil, and about half or one inch from it. With this instrument it was observed that a spark often proceeded from the point of the wire, which occasioned an insufferable pain; for which reason Mr. PARTINGTON, who spares no pains to advance this branch of physic, thought of improving this instrument by fixing a wooden point upon the pointed wire, by which means the former inconvenience was entirely removed, and the stream of electric fluid was rendered more efficacious, and more easily manageable.

This, as far as I am informed, was the first time that this most excellent method of throwing the electric fluid, *viz.* with a wooden point, was used.

N. B. The directors described in the preceding pages, the principal of which were contrived by Mr. PARTINGTON, answer every required purpose, much better than the above-described instrument of Mr. FERGUSON.

C A S E II.

The following case is related by Mr. LOVETT, in his *Electricity rendered useful*;

“ Having observed the great efficacy of the electrical æther, in soon relieving most kinds of inflammations, I was inclined to think the same salutary effects would appear when applied to the St. Anthony's Fire; but when a case of that sort offered, the inflammation was so great, that at first sight I almost despaired of success.

“ About the middle of the day I made the first trial, and before night the swelling was much abated, and in a few days quite cured.

“ The operation was simply drawing sparks with a finger, or an iron style, while the

the person was electrified on the insulating stool."

C A S E III.

The following case is also related by Mr. LOVETT :

" ANN THOMPSON, in Little Fish-street, Worcester, was troubled with a fistula near the inner corner of her eye, which broke out, and healed, no less than seven times. The last time it healed, it continued well for some time ; after which it began with a small swelling, and continued growing larger, till it was as big as a filbert ; when she was advised to try Electricity. After the swelling was electrified, it soon decreased, till it was entirely dispersed ; and has continued well for more than two years, without the least symptom of any return of the disorder. — The operation was simply drawing sparks from the part affected."

C A S E IV.

The late Mr. FERGUSON being at Bristol, was seized with a violent fore throat, so that he could not swallow any thing. Being willing to try the power of Electricity, Mr. ADLAM, of that city, performed the operation; which was merely drawing sparks from the throat. The electrization was repeated half an hour after, and was attended with so good and remarkable an effect, that in about one hour's time Mr. FERGUSON could both eat and drink without pain.

C A S E V.

The following two cases are related by Mr. JOHN BIRCH, Surgeon.

“ A young woman, at the age of twenty-two, desired my advice for a tumor on her thigh, which followed an unhappy accident she met with two years before. Her case was attended with many complicated symptoms, and, among them, a suppression
 sion

sion of the menses, which had lasted seven months. I thought it right to relieve, if possible, this symptom, before I proceeded to perform the operation, which was necessary for the tumor.

“ For three successive days I passed some electric shocks through the region of the pelvis; and on the fourth, she was attacked with a violent pain in her side, which left her on applying the shocks to that part. In about three hours it returned, and I was sent for. I repeated the shocks, and the pain again vanished. I visited her six hours after, when the pain had begun to attack the side.—I passed a stronger shock, which removed it, and she slept well the whole night.—The next day, being the fifth, the menses appeared, and flowed gently for three days; but ceasing then, the pain of the side returned, and was so violent, that I was sent for in a hurry.—When I came to her, I found her in great agony; but being informed of the cause, I begged to make trial of Electricity once more, which she readily consented to, as she had experienced such instantaneous relief before.

—On

—On its application, the pain ceased.—A very short time after, the flux came on, and continued two days.—I attended her for several weeks after, upon the former account, and had the pleasure to see her recover from all her complaints.”

C A S E VI.

“ I was sent for to a lady, who had been afflicted with painful ulcers on both her legs, for more than fifteen months.—They came after a lying-in, and had never healed. The legs were swelled, but the ulcers had no malignant appearance.—She told me, that since her last miscarriage, which was then more than ten months, she had never been regular.—She attributed the pain and swelling of her legs to that cause; and, upon enquiry, I found that she was sensible of an endeavour of nature to relieve herself at regular periods, and that the pain she suffered at those times was alleviated by a bloody discharge from the ulcers.—I applied the proper dressings and bandages to the parts, and waited the approach of that period.

In

In about ten days, a pain seized her back, and she began to complain of her legs: I then electrified her; and the next day she was taken out of order, and continued so the whole week.—The ulcers mended from that time, and were healed in three weeks afterwards.”

The reader may rest assured, that cases of this sort are so frequent, that perhaps Electricity may be considered as a sure remedy for the arrest of those natural fluxes.

C A S E VII.

The following case is extracted from the LXVIIIth volume of the Philosophical Transactions.

A Cure of a muscular Contraction by Electricity. By Mr. MILES PARTINGTON, in a Letter to WM. HENLY, F. R. S.

*Charles-street, Cavendish-square,
June 13, 1777.*

“DEAR SIR,

“It is some time since, you informed me that you had mentioned to Sir JOHN

“ PRINGLE, Miss LINGFIELD’s cure by
“ Electricity; that it excited his attention;
“ and was his opinion, that the com-
“ munication of it to the Royal Society
“ would be deemed important and useful.
“ I hope you will not blame my delay in
“ the compliance with your request. I
“ have waited for no other purpose, than
“ to obtain the latest account of the per-
“ manency of those good effects, which
“ she had then but recently experienced,
“ from our electrical experiments upon
“ her. Of these advantages we have both
“ had repeated confirmation; and I may
“ now, I believe, with strict propriety,
“ from the notes I made for my own satis-
“ faction, submit the following particulars
“ of them to the inspection of whomsoever
“ your judgment shall direct, or to appro-
“ priate them to any other purpose you
“ please. As you were present when I first
“ waited on this unhappy young lady, you
“ will recollect the condition in which we
“ found her. Her head was drawn down
“ over her right shoulder; the back part
“ of it was twisted so far round, that her
“ face turned obliquely towards the oppo-
“ site

“ site side, by which deformity she was
 “ disabled from seeing her feet, or the steps,
 “ as she came down stairs. The *sterno-*
 “ *mostoideus* muscle was in a state of con-
 “ traction and rigidity. She had no ma-
 “ terial pain on this side of her neck ; but,
 “ owing to the extreme tension of the
 “ teguments of the left side, she had a pain
 “ continually, and often it was very vio-
 “ lent, particularly in sudden changes of
 “ the weather. Her pulse was weak,
 “ quick, and irregular. She was subject
 “ to a great irritability ; had frequently a
 “ little fever, which came on of an even-
 “ ing, and left her before morning : her
 “ spirits were generally exceedingly op-
 “ pressed ; and at times she was slightly
 “ paralytic.

“ She dated the origin of her disorder
 “ at something more than two years from
 “ that period. She was suddenly seized,
 “ going out of a warm room into the cold
 “ air, with a pain upon the back of her
 “ head, which admitted of small abate-
 “ ment for some months, contracting gra-
 “ dually the muscles to the melancholy
 “ deformity

“ deformity we then beheld; and not-
 “ withstanding every prudent means had
 “ been used to subdue it, and she strictly
 “ adhered to every article prescribed to her
 “ by the faculty, she was sensible of little
 “ variation since, and that rather on the
 “ unfavourable side.

“ I urged her to make a trial of Electri-
 “ city. She was willing while she was in
 “ London to try the experiment; and
 “ though the weather was remarkably
 “ tempestuous, she came to me the first
 “ tolerable day, and was electrified the first
 “ time, February 18, 1777.

“ I placed her in an insulated chair, and,
 “ connecting it by a chain to the prime
 “ Conductor of a large electrical machine,
 “ I drew strong sparks from the parts af-
 “ fected, for about four minutes, which
 “ brought on a very profuse perspiration
 “ (a circumstance she had been unaccus-
 “ tomed to) which seemed to relax the
 “ *moftoideus* muscle to a considerable degree;
 “ but as the sparks gave her a good deal of
 “ pain, I desisted from drawing them, and
 “ only

“ only subjected her a few minutes longer
 “ to the admission of the fluid, which passed
 “ off without interruption from the pores
 “ of her skin and adjacent parts. The next
 “ time she came to me, was the 24th of
 “ the same month. As she had been in the
 “ afternoon of the first day’s experiment a
 “ good deal disordered, I changed the mode
 “ of conducting the operation, and sat her in
 “ a common dining chair, while I dropped,
 “ for five minutes, by the means of a large
 “ discharging rod with a glass handle, very
 “ strong sparks upon the *mostoideus* muscle,
 “ from its double origin at the *sternum* and
 “ *clavicula* to its insertion at the back of the
 “ head. She bore this better than before,
 “ and the same good effect followed in a
 “ greater degree, and without any of the
 “ subsequent inconveniences. I saw her
 “ the third time on the 27th. She assured
 “ me she had escaped her feverish symp-
 “ toms of an evening, and that her spi-
 “ rits were raised by the prospect of getting
 “ well; that since the last time I electri-
 “ fied her, she had more freedom in the
 “ motion of her head, than she had ever
 “ experienced since the first attack of her
 “ disorder.

“ disorder. I persisted in electrifying her
 “ after the same manner, March 3d, 5th,
 “ 6th, 7th, and 9th ; from each time she
 “ gained some advantage, and her feverish
 “ tendency and nervous irritability went
 “ off entirely.

“ The weather now setting in very un-
 “ favourable, and fearful of losing the
 “ advantages we had happily reaped from
 “ our early efforts, I requested the favour
 “ of you, as the next-door neighbour, to
 “ electrify her every evening while she
 “ was in town, and she might, if any al-
 “ teration took place, see me occasionally.
 “ Fortunately for her, you accepted the
 “ proposal ; and to your judgment and
 “ caution in the conduct of it, for the next
 “ fortnight (three evenings only excepted)
 “ you brought about the happy event ; and
 “ have received her testimony of gratitude,
 “ for relieving her from a condition, under
 “ which life could not be desirable, to a
 “ comfortable association with her family
 “ and friends.

“ I am, &c.”

“ The

“ The method I pursued was, to place the lady upon a stool with glass legs, and to draw strong sparks, for at least ten minutes, from the muscles on both sides of her neck. Besides this, I generally gave her two shocks, from a bottle, containing fifteen square inches of coated surface, fully charged, through her neck and one of her arms, crossing the neck in different directions. This treatment she submitted to with a proper resolution; and it gave me sincere pleasure to find it attended with the desired success.

W. HENLY.”

C A S E VIII.

The following case is extracted from the LXIXth vol. of the Philosophical Transactions.

An Account of a Cure of the St. Vitus's Dance, by Electricity. In a Letter from ANTHONY FOTHERGILL, M. D. F. R. S. at Northampton, to W. HENLY, F. R. S.

Northampton, Oct. 28, 1778.

S I R,

Agreeable to my promise, I now proceed to give you some account of a recent

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N

cure

cure performed by Electricity, which will, I think, afford you much pleasure.

Ann Agutter, a girl of ten years of age, of a pale emaciated habit, was admitted an out-patient at the Northampton Hospital on the 6th of June last. From her father's account it appeared (for she was speechless, and with difficulty supported from falling by two assistants) that she had for six weeks laboured under violent convulsive motions, which affected the whole frame, from which she had very short intermissions, except during sleep; that the disease had not only impaired her memory and intellectual faculties, but of late had deprived her of the use of speech.

Volatile and fetid medicines were now recommended, and the warm bath every other night, but with no better success, except that the nights, which had been restless, became somewhat more composed. Blisters and anti-spasmodics were directed, and particularly the flowers of zinc, which were continued till the beginning of July, but without the least abatement of the symptoms;

symptoms ; when her father growing impatient of fruitless attendance at the hospital, I recommended, as a *dernier resort*, a trial of Electricity, under the management of the Rev. Mr. UNDERWOOD, an ingenious electrician. After this I heard no more of her till the first of August, when her father came to inform me that his daughter was well, and desired she might have her discharge. To which, after expressing my doubts of the cure, I consented ; but should not have been perfectly convinced of it, had I not received afterwards a full confirmation of it from Mr. UNDERWOOD, dated September 16 ; an extract from whose letter I will now give you in his own words.

“ I have long expected the pleasure of
 “ seeing you, that I might inform you
 “ how I proceeded in the cure of the poor
 “ girl. As the case was particular, I have
 “ been very minute, and wish you may
 “ find something in it that may be useful
 “ to others. If you think it proper, I beg
 “ you will state the case medically, and
 “ make it as public as you please.

“ July 5. On the glass-footed stool for
 “ thirty minutes : sparks were drawn from
 “ the arms, neck, and head, which caused
 “ a considerable perspiration, and a rash
 “ appeared in her forehead. She then
 “ received shocks through her hands, arms,
 “ breasts, and back ; and from this time
 “ the symptoms abated, her arms begin-
 “ ning to recover their uses *.

“ July 13. On the glass-footed stool
 “ forty-five minutes : received strong
 “ shocks through her legs and feet, which
 “ from that time began to recover their
 “ wonted uses ; also four strong shocks
 “ through the jaws, soon after which her
 “ speech returned.

“ July 23. On the glass-footed stool
 “ for the space of one hour : sparks were
 “ drawn from her arms, legs, head, and
 “ breast, which for the first time she very
 “ sensibly felt ; also two shocks through
 “ the spine. She could now walk alone ;
 “ her countenance became more florid,
 “ and all her faculties seemed wonderfully

* The coated bottle held near a quart.

“ strengthened ;

“ strengthened ; and from this time she
“ continued mending to a state of perfect
“ health.

“ Every time she was electrified posi-
“ tively, her pulse quickened to a great
“ degree, and an eruption, much like the
“ itch, appeared in all her joints.”

Thus far Mr. UNDERWOOD. To complete the history of this singular case, I this day (Oct. 28) rode several miles, on my return from the country, to visit her ; and had the satisfaction to find her in good health, and the above account verified in every particular ; with this addition, that at the beginning of the disease, she had but slight twitchings, attended with running, staggering, and a variety of involuntary gesticulations, which distinguish the St. Vitus's Dance ; and that these symptoms were afterwards succeeded by convulsions, which rendered it difficult for two assistants to keep her in bed, and which soon deprived her of speech and the use of her limbs. The eruptions which appeared on the parts electrified soon receded,

N 3

without

without producing any return of the symptoms, and therefore could not be called critical, but merely the effect of the electrical stimulus. Having given her parents some general directions as to her regimen, &c. I took my leave, with a strong injunction to make me acquainted, in case she should happen to relapse. Before I conclude, it may not be improper to observe, that some time ago, I was fortunate enough to cure a boy who had long had the St. Vitus's Dance (though in a much less degree) by Electricity. A violent convulsive disease, somewhat similar to the above, though, if I recollect right, not attended with the *aphonia*, was successfully treated in the same way by Dr. WATSON, and is recorded in the Philosophical Transactions. May we not then conclude, that these facts alone, and more might perhaps be produced, are sufficient to intitle Electricity to a distinguished place in the class of anti-spasmodics?

I am, &c.

CASE IX.

The following is one of those cases in which the use of Electricity was attended with bad success: this case was related by Dr. HART of Shrewsbury. See the Philosophical Transactions, VOL. XLVIII.

A girl, aged about sixteen, whose right arm was paralytic, being electrified the second time, became intirely paralytic, and remained in that state for about a fortnight; then the superadded paralisy was removed, by means of some medicines; but the arm which was before paralytic, remained so. It should be also added, that this arm was very much wasted in comparison to the other. Notwithstanding the first bad accident, it was resolved to make another trial of Electricity. But after using this treatment for three or four days, she became again universally paralytic, and even lost her voice, and could swallow with difficulty. This second accident plainly shewed

the bad effects of Electricity in that case, and the girl, although afterwards relieved of her additional paralysis, remained in the same state she was before the use of Electricity.

In this case, it is suspected that Electricity was improperly managed; at that time, it being usual to give strong shocks, which perhaps were pernicious in the above-mentioned case.

C A S E X.

The following case was performed under the direction of the learned Dr. WM. WATSON, F. R. S.

A girl belonging to the foundling-hospital, aged about seven years, being first seized with a disorder occasioned by the worms, was at last, by an universal rigidity of the muscles, reduced to such a state, that her body seemed rather dead than alive. After that other medicines had been ineffectually administered

administered for about one month, she was at last electrified intermittently for about two months, after which time she was so far recovered, that she could, without pain, exercise every muscle of her body, and perform every action as well as before she had the distemper.

The intelligent reader must have undoubtedly remarked, that in some of the above cases, the electrization administered was rather strong, and different from the general rules given previous to the narration of the cases. But it must be observed, that some of the above cases happened before the principal methods of electrifying, which are now used by the best practitioners, were introduced.—Perhaps, in similar cases, the same salutary event might be produced by a more gentle electrization.

*A Letter from Mr. MILES PARTINGTON
to the Author.**Cavendish Square, August the 10th, 1781.*

S I R,

As-the possibility of a cure of a fistula lacrymalis by Electricity has been publicly questioned, I am very glad to comply with your request, in stating the successful treatment of a disease of this kind under my own inspection.

Ann Woodward, between 20 and 30 years of age, was recommended to my care by Mrs. Swift, of King Street, Bloomsbury, in whose service she then lived—I was told she had a fistula lacrymalis, which had resisted every attempt to relieve her. I shall describe the situation she was in when I first saw her, and shall add her own account anterior to that period. There was a very violent inflammation in the left eye, attended with excessive pain, and almost continual flux of tears down the cheek, the sharpness of which had considerably exco-
riated

riated the skin. A little prominence was perceivable on the inner angle of the eye, from which might be generally pressed a small quantity of matter. The inflammation had been kept up with little abatement for six months, during which time a cooling regimen had been particularly enjoined her, and was strictly complied with. Since the inflammation became violent, she had constantly awoke in pain, which lasted till twelve o'clock at noon, and was then tolerably easy the rest of the day. She told me, that she had, as long as she remembered, been subject to a weak and watery eye, but it had never given her much concern, till she received a cold in it upon her coming to London. In every other respect she was remarkably healthy.

My first object was to relieve her of the pain. For this purpose I conveyed the electric fluid from a wooden point, which generally at the time blunted the acuteness of the sensation; but which, if by bringing it near to her eye the fluid was concentrated, it always increased it to a great degree, though this went off by
being

Being left to itself, or repeating the milder method. I continued in this course of treatment for three weeks, when the inflammation was nearly subsided, and the pain entirely gone away. Still perceiving the matter to ooze from the inner angle, I ventured to pass a single electric shock down the duct of the nose, which I effected by placing one of the directors upon the lacrymal sac, and the other up the nostril, for the convenience of a more immediate local conveyance. This gave her much pain after the operation, and it remained all the rest of the day. I found in the morning that she could hardly bear me to press upon the sac, and very little matter came from it. I then passed four shocks, in the smallest degree I could convey them, and to be felt, which were not attended with so much pain. At bed-time there came on a great throbbing in the part, and in the course of the night a large quantity of matter burst down the nostril, when she became immediately easy. Some matter continued to come away for about four days, and she appeared to be perfectly well. Her eye has been since in a stronger state than it ever was before.

If this should still want additional strength, I am willing to give you farther instances of relief in this disease by Electricity, though they have not been so effectually cured.

I shall now add a few observations, which may perhaps merit your notice. In order to increase the power of electrization, I have added a very large coated jar to the prime Conductor of my electrical machine. This jar is placed upon a mahogany stand, so that the knob of it touches the Conductor. The insulated chair is also in contact with the said Conductor, and the patient is seated in it as usual. With this disposition of the apparatus, the wheel of the machine is first turned a few times round; then I apply the metallic rod to the patient, in order to draw the sparks through the cloaths, or the stream of electric fluid by a wooden point, if the disease seem to require such treatment; and I find, that by this means the effects of the electrization are considerably increased, the pungency of the sparks is felt much deeper into the electrified part of the body; the heat occasioned
by

by it is also greater, and therefore seems to be more efficacious for internal complaints. Add to this, that the usual inconvenience of the dissipation of the electric fluid into the air is considerably prevented.

This disposition of the apparatus does also answer another purpose, which is that of electrifying a patient, without having any assistant in the room; for after the jar is charged, the turning of the wheel may be discontinued, and the patient may continue under the electrization. No shock is to be feared from this apparatus; for, since the wooden stand upon which the jar is fixed is a bad Conductor, the discharge can only be made gradually.

I have made another addition to my directors, or rather have contrived a new director, by which an electrified stream of water or other fluid is thrown upon any part of the body. This director consists of a small glass tube about 3 inches long, and a quarter of an inch in diameter, one extremity of which is drawn to a very fine point, such as the water can hardly pass through.

through. This tube I fasten to an insulating handle, which being made like a pair of pincers, holds it by the middle ; I then pour a little water or other fluid into the tube, and by means of a wire connect it with the prime Conductor. When the machine is in motion, the stream of water, which the electric fluid forces out of the tube, is very much subdivided, and, when directed upon the face, or any naked part of the body, gives an agreeable sensation, which not only proves very refreshing to patients, but in cases of great irritation of the nerves is often attended with permanent relief. The short experience I have had of these directors does not enable me to determine how far they may be useful ; but in several instances they have afforded considerable relief, when other modes of electrization proved useless.

In the course of my practice, I have observed a very remarkable effect of Electricity upon the human body, which is, that it removes costiveness in those persons that are electrified, especially along the course of the alimentary canal. I must observe,

that it does by no means increase the evacuations of ordinary good habits of body, but only reinstates the usual discharge in case of costiveness. This effect seems to take place because the electrization gives vigour and energy to the fibres of the debilitated intestines, in the same manner as it restores the lost motion of more external muscles.

I am,

Dear Sir,

Yours, &c.

MILES PARTINGTON.

A Letter.

*A Letter from Dr. JAMES LIND to the Author.**Windsor, June the 17th, 1784.*

DEAR SIR,

I here send you the account of a remarkable case relieved by Electricity whilst I was at Bombay: if you think it worth publishing, I beg you will insert it in the next publication of your Medical Electricity.

“ The wife of an officer of the artillery at Bombay, during the last months of her pregnancy, gradually lost the use of her lower limbs, as if it had been a paralysis, occasioned by the pressure of the fœtus upon the nerves which go to those extremities. Her pregnant state did not allow the application of any remedy for the relief of the disorder. She came to her full time, was safely delivered, and though she soon recovered in every other respect, yet, contrary to every expectation, the paralysis still remained; nor could it be in the least reliev-

ed by any of the various medicines, which were administered for about seven months, which had elapsed from the time of her delivery, and until I first visited her, which was in June 1780.

“ Upon enquiry finding that, of the many remedies likely to afford any relief in such a case, Electricity alone had not yet been tried, I immediately recommended the application of it. But the difficulty was to excite an electrical machine in an atmosphere so excessively moist as that of Bombay was at that time, the rainy season being already set in ; however, the husband of the patient, being the superintendant of the Military Laboratory of that place, proposed to try whether an electrical machine could be made to act in a heated room ; such as they used for the drying of gunpowder. Accordingly a small stucco'd room in his house was heated by means of burning charcoal, then the doors and windows were thrown open, and an electrical machine being brought in, was found to act very powerfully. Things being thus prepared, my patient began to be electrified, first by

3

giving

giving sparks to her legs and thighs, and afterwards by passing about twenty very small shocks up one leg and down the other. The effect was really surprising; for, after the first electrization, she was so far relieved as to be able to walk up some steps without any help, which she had not been able to do for many months before. By the second days electrization, which was performed exactly as in the preceding, she was enabled to walk out, and visit several of her friends in the neighbourhood. The third day's electrization compleated the cure, and she went about with all the easiness and alacrity in the world. I afterwards received a letter from her husband, dated May the 29th, 1781, informing me of her continuing in perfect health."

Faithfully yours.

APPENDIX.

Nº I.

OF THE VINDICATING ELECTRICITY.

1. **A** B, *ab*, fig. 6, of Plate IV. represents a plate of glass, coated on both sides with the two metallic coatings CD, *ca*, which are not stuck to the glass plate, but are only laid upon it.

From the upper coating CD, three silk threads proceed, which are united at their top H, by which the said coating may be removed from the plate in an insulated manner, and may be presented to an electrified electrometer, as represented in fig. 7, in order to examine its Electricity. FG is a glass stand, which insulates and supports the plate, &c.

2. Let

2 Let the plate A B, *ab*, be charged in the common manner, by means of an electrical machine, so that its surface A B may acquire one kind of Electricity, (which may be called K) and the opposite surface *ab* may acquire the contrary Electricity, (which we shall call L). Then, if the coating C D be removed from the plate, and be presented to an electrified electrometer, as represented in fig. 2, it will be found possessed of the Electricity K, *viz.* of the same kind with that which was communicated to the surface A B of the glass plate; from whence it is deduced, that the surface A B has imparted some of its Electricity to the coating. Now, this disposition of the charged plate to give part of its Electricity to the coating, is what the learned F. BECCARIA nominates the *Negative vindicating Electricity*.

3. If the coating be again and again alternately laid upon the plate and removed, its Electricity K will be found to decrease gradually, till after a number of times (which is greater or less, according as the edges of the plate insulate more or less, ex-

actly) the coating will not appear at all electrified. This state is called *the limit of the two contrary Electricities*; for if now the above-mentioned operation of coating and uncoating the plate be continued, the coating will be found possessed of the contrary Electricity, viz. the Electricity L. This Electricity L of the coating is weak on its first appearance, but it gradually grows stronger and stronger till a certain degree; then insensibly decreases, and continues decreasing until the glass plate has entirely lost every sign of Electricity.

By this change of Electricity in the coating, it is deduced, that the surface A B of the glass plate changes property; and whereas at first it was disposed to part with its Electricity, now (*viz. beyond the limit of the two contrary Electricities*) it seems to *vindicate* its own property, that is, to take from the coating some Electricity of the same kind with that of which it was charged: hence this disposition was by F. BECCARIA called the *Positive vindicating Electricity*.

4. This

4. This positive vindicating Electricity never changes, though the coating be touched every time it is removed. It appears stronger, and lasts a very considerable time after the plate has been discharged; which is a very surprising property of glass, and probably of all good and solid electrics.

5. If, soon after the discharge of the plate, the coating be alternately taken from the plate, and replaced, but with the following law, *viz.* that when the coating is upon the plate, both coatings be touched at the same time, and when the coating is off, this be either touched or not; then the surface A B of the plate, on being uncoated every time, takes a quantity of Electricity, which it alternately loses every time it is coated*.

6. On removing the coating in a dark room, a flash of light appears between it and the glass, which is still more conspi-

* This may be proved by touching an insulated electrometer with the coating, when this is standing upon the plate, and when separated from it.

cuous, if the coating be removed by the fingers being applied immediately to it, *viz.* not in an insulated manner; because, when the coating is not insulated, the glass plate can give to, or receive from it, more of the electric fluid, and that more freely, than otherwise.

7. It is observable, that in the negative vindicating Electricity, the glass loses a greater or less portion of Electricity, in an inverse proportion of the charge given to the plate, *viz.* the part lost is greater when the charge has been the weaker; for in the positive vindicating Electricity, the force of receiving Electricity is the stronger, when the charge has been stronger, and contrarywise.

8. If, after every time that the coating CD is removed, the atmospheres E, e, that is, the air contiguous to the surface of the glass plate, be examined, they will be found electrified as in the following table, *viz.* the threads of an electrometer, brought within one or two inches, or more, of the surfaces A B, *ab*, will diverge with Electricities

tricitities contrary to those expressed in the table.

During the time of the negative vindicating Electricity

{	the air E,	{	moderately	{	moderately L
	if the plate		high -		o
	has been		very high -		moderately K
	charged				

the air ϵ is electrified L.

During the time of the positive vindicating Electricity

{	the air E	{	are electrified L.
	The air ϵ		

9. Although we are not acquainted with the cause of vindicating Electricity, any farther than to consider it as a disposition or property of charged glass, yet the phenomena of the Electricities of the air, contiguous to the surfaces of the plate, seem to be a proper consequence of Dr. FRANKLIN's theory of Electricity, and are accountable by it; for it is a well-known principle of that theory, that when one side of a coated electric, fit to receive a charge, acquires a greater quantity of Electricity than the opposite side can acquire of the contrary Electricity, then both sides of that electric appear possessed of the same kind of Electricity, namely, of that communicated

municated to the first-mentioned side. Now, when in the negative vindicating Electricity, the surface *A B* of the glass plate gives part of its Electricity to the coating, then the other side *ab*, being more electrified *L*, than the side *A B* is electrified *K*, it is plain that, according to the said principle, both sides must appear electrified *L*. But in the positive vindicating Electricity, the side *A B* of the glass plate receives some Electricity of the kind *K* from the coating, therefore both sides must affect the air with the Electricity *K*.

10. There remains only to be explained the reason why, when the plate has received a high charge, the air *E*, during the time of the negative vindicating Electricity, appears electrified *K*, whilst the air *e* is electrified *L*. In order to render this explanation more intelligible, let us suppose the glass plate to have been electrified positively on the side *AB*; then, in the negative vindicating Electricity, the surface *A B*, on being uncoated, loses a part of its Electricity, which is so much the greater as the charge has been the less (§ 7.); therefore,

therefore, when the charge has been moderate, A B loses a greater portion of electric fluid, than that with which the air e can supply the surface ab ; hence the surface ab will remain more negatively electrified than the surface A B is positively; consequently, according to the above-mentioned principle, (§ 9.) both the atmospheres E, e , must appear in a negative state when the charge has been a certain degree higher; then the surface A B, on being uncoated, loses just so much of the electric fluid as the air e can give to ab , therefore the air will not appear electrified. But when the charge has been very high, A B loses a less portion of electric fluid than the air e can give to ab ; therefore e , by having given some of its natural electric fluid to ab , will appear negative, and E will appear positive in a small degree. If the plate be supposed to have been charged negatively on the side A B, the explanation of the phenomena is the same, changing only the name of *positive* Electricity into *negative*, &c.

11. This property of charged glass, called vindicating Electricity, is observable
also

also when two glass plates, laid one over the other, and coated on their outward surfaces only, are charged jointly like one plate. Suppose A B, C D, fig. 8, to represent the two plates charged together, *viz.* by having presented the coating F to the prime Conductor, and having at the same time connected the coating G with the ground, in which state, it is easy to conceive, that the upper surface of the plate A B would be positive, its under surface would be negative, the upper surface of the plate C D, *viz.* the surface contiguous to the plate A B, would be positive, and its opposite surface G would be negative. Now if these plates, after having been charged, be alternately separated and joined, without ever touching their coatings, it is plain that their surfaces, contiguous to one another, whenever the plates are separated, will uncoat each other, consequently the phenomena of vindicating Electricity will take place, that is, each of the inside or naked surfaces, when the plates are first separated, will lose part of its Electricity. This lost Electricity gradually decreases till it vanishes, after which period, each of
the

the said surfaces will gradually recover part of its lost Electricity, &c.

12. By the principle noticed above, (§ 9.) when one surface of either plate has acquired a quantity of one kind of Electricity more than the opposite surface has acquired of the other, then both surfaces of that plate must appear possessed of that and the same kind of Electricity; hence it follows, that when the plates A B, C D, are at first separated for a certain number of times, *i. e.* during the negative vindicating Electricity, the plate A B must appear positive on both sides, and the plate C D negative on both sides; but after the *limit of the two contrary Electricities*, when the positive vindicating Electricity has taken place, then the plate A B will appear negative on both sides, and the plate C D positive on both sides.

13. The adhesion of the plates to one another keeps pace with the vindicating Electricity; so that it is very strong at first, but gradually decreases with the negative vindicating Electricity, till it becomes insensible;

fenfible ; but after the limit of the two contrary Electricities it appears again, and then it increafes and decreases with the positive vindicating Electricity.

14. Every other particular relating to the phenomena of vindicating Electricity, exhibited with one plate, does alfo take place in the experiment with two plates ; except the phenomena confidered above (§ 10.), which the two plates cannot exhibit, on account that they are not capable of receiving a very high charge, as a fingle plate is ; which high charge is abfolutely neceffary to produce that appearance.

N^o. II.OBSERVATIONS UPON THE CONDUCTORS
OF LIGHTNING.

SINCE the publication of the First Edition of this Treatise, it happened that a house belonging to the Board of Ordnance, at Purfleet, was struck by lightning, though furnished with a Conductor. This accident excited anew the controversy relating to the construction of Conductors to secure houses from the effects of lightning, especially relating to their termination; and various experiments were made by very able Electricians, in order to decide the controverted point. Mr. B. WILSON and Mr. ED. NAIRNE, both members of the Royal Society, were the principal actors in this experimental investigation; the former giving constantly the preference to short Conductors terminating in a ball, and the latter preferring long Conductors acutely pointed; which has been and is the prevailing opinion with almost all the principal

cial Electricians in England, as well as abroad; beginning from the first inventor of those Conductors (the great philosopher Doctor FRANKLIN). Mr. WILSON, the principal and almost the sole opponent of the Franklinian construction of Conductors, exhibited some ingenious electrical experiments upon a large scale; which threw great light upon the property of points in respect to Electricity, and seem at first sight to decide the question in favour of knobbed Conductors, as will appear by the following pages. On the other side, Mr. NAIRNE performed some well-imagined experiments, which seem to establish, beyond any doubt, the prevailing opinion in favour of pointed Conductors; which was afterwards still more confirmed and elucidated by Lord MAHON, in his learned work, entitled, *Principles of Electricity*, and published in the year 1779.

Notwithstanding those various disquisitions, and new observations, it seems that what I had previously written, relating to the construction of Conductors, did not require any material alteration; hence I thought proper to reprint, in this Third Edition,

Edition, exactly that which had been advanced relating to Conductors of lightning in my first publication ; and have reserved for this dissertation, to make mention of those additional remarks, which, in the present more advanced state of the science, are necessary to be noticed. Mr. WILSON, Mr. NAIRNE, and others, must excuse my giving a very short and summary account of their valuable experiments, since the limits of this work are by far too short to admit a full account of their observations. I shall just mention the principal facts ascertained, so as to make evident the deduction which naturally follows them, and which is necessary to establish the present improved theory of Conductors ; omitting those remarks which seem to be not essential, and even dispensing with the particular description of the various apparatuses used for this purpose. The *Board-house*, struck by lightning on the 12th of May 1777, had a pointed iron spike, which projected ten feet above the middlemost and highest part of its roof, and which had a continued metallic communication to the ground. The lightning did no other

damage to this house, than to throw down a few stones from one of its upper corners, which were next to two iron cramps; which cramps had not a metallic communication with the Conductor. This corner was forty-six feet distant from the top of the Conductor. In this case it is difficult to say, whether the lightning struck the Conductor first, or the corner of the house just over the above-mentioned iron cramps, and from thence, being passed to the metal which communicated with the Conductor, was conducted to the ground, without causing any farther damage to the house. In the first case, the point of the Conductor would, in all probability, have been fused, as is generally the case; but no mark of fusion could be perceived on it. The second case seems not very likely to have happened, since the Conductor was far above the corner that was struck, and since the lightning is known to strike the most elevated objects, and those which have a better communication with the earth, in preference to any other *. In any case, the

* Mr. NAIRNE concludes the account of his above-mentioned experiments with the following passage:

“ I must

the only useful remark that can be drawn from this accident is, that all the metallic parts, that are in a building, should be connected with the Conductor, otherwise it is not unlikely, but that, either by a direct stroke, or by a lateral explosion, the house may suffer some damage from lightning. Mr. WILSON, who had formerly declared his opinion against elevated and pointed Conductors, derived from this accident a strong proof apparently in favour of his theory,

“ I must beg to intrude a little more on your time,
“ to remark on that part of Mr. WILSON's paper,
“ where, from his experiments, he seems to conclude,
“ that the lightning at Purfleet first struck on the
“ point of the rod of the Conductor, and then, by a
“ lateral part of that stroke, struck the cramp on the
“ coping-stone. I believe, if he had examined the
“ situation of the stone, and the place where the
“ cramp was struck, he would have found, that, if the
“ lightning had struck on the point of the Conductor,
“ that, to have produced that effect on the stone, it
“ must, after it had struck on the point, and passed
“ down a quantity, have struck from the metal up into
“ the air, then down again on the cramp, and then
“ again to the metal it had left; for the small dent or
“ hollow made by the lightning was on the upper sur-
“ face of the stone, and yet the metallic communication
“ to the earth continued from the point under the stone

theory, and soon began to perform several experiments, in which the natural accident was imitated by art*. Mr. WILSON's great apparatus was fixed in the Pantheon, Oxford-street. It consisted principally of the following parts:—A cylinder, 16 inches in diameter, and 155 feet long, covered with tin-foil, formed the prime Conductor, which was charged by a good electrical machine of the common sort. This vast Conductor was suspended by various silk strings, at a convenient distance

“ which was struck. It appears more probable to me,
 “ from the trifling damage it did, that the charged
 “ cloud had passed over the pointed Conductor, and
 “ had been exhausted of a great part of its Electricity
 “ in passing; and that, after it had passed, it was at-
 “ tracted down lower by a ridge of hills that was be-
 “ yond, and that the cloud being out of the influence
 “ of the point to prevent its striking, the end of the
 “ cloud might strike at an angle in the cramp, and so
 “ to the metallic part of the Conductor, which was
 “ only about 7 inches below. I shall conclude with
 “ observing, that Mr. HENLY and myself had the
 “ pointed rod of the Conductor at Purfleet taken down
 “ to examine the point; but we found no appearance
 “ on it that shewed that it had been struck.”

* The account of those experiments is inserted in the 68th vol. of the Phil. Trans.

from

from the floor and walls. To this Conductor there was added a wire 4800 feet long, which was also supported by silk strings, and, on account of its prodigious length, was bent in a great many places, going backwards and forwards in various directions. Sometimes this wire was separated from the great cylinder; but, for the generality of experiments, they were made to communicate together, so as to form one extensive Conductor.—By means of a proper frame and machinery, a wooden model of the above-mentioned house, that was struck by lightning, was made to pass with different required degrees of velocity under and across one end of the great cylinder. This model was furnished with a Conductor at top, which was sometimes terminated in a point, and at other times ended in a ball, but which was made to communicate with the earth by as good a metallic communication as can be desired by the most scrupulous experimenter. Whilst the model of the house was kept at a proper distance from the great cylinder, and after a known number of turns of the wheel, the model being let go, passed under the end of

the cylinder with any required velocity, and at the moment that it passed immediately under the charged cylinder, it received the stroke from it upon its Conductor, &c. Now the principal experiments which Mr. WILSON made with this apparatus, are briefly expressed in the following articles :

1. When the model was furnished with a sharp Conductor, on being made to pass under the charged cylinder, it drew off a good deal of the electric fluid from it in a silent manner, and that absorption, as it may be said, began long before the model came quite under the cylinder, as was shewn by the appearance of light, &c. The charge which afterwards remained in the cylinder was inconsiderable : all which shews the tendency that a point has to draw the electric fluid silently, and from a distance.

2. If, instead of a point, the model was furnished with a knobbed Conductor of the same length with the pointed one, the quantity of electric fluid drawn off in repeating

peating the above experiment was not so considerable as before, and it was almost nothing, if the knobbed Conductor was much shorter than the pointed one, as could have been expected.

3. When the model with the sharp Conductor was made to pass under the cylinder fully charged, the pointed Conductor was generally struck with a full and strong explosion; whereas, if the Conductor was terminated in a ball (though of an equal length with the pointed Conductor, and consequently equally distant from the cylinder when the model was just under it) it was not struck, the cylinder remaining charged, &c.

4. “ The weight which moved the model in the preceding experiment, was gradually reduced till it was nearly balanced by the friction; and when the motion was rendered so slow as seven feet seven inches in seven seconds, it was very little accelerated; and in this state the great cylinder being charged, the model was suffered to pass; and, though the

“ velocity was less than three quarters of a
“ mile in an hour, the point was struck.”

The intelligent reader may remark, that by the above-mentioned observations, the already-known properties of points were clearly shewn : that the very reasons before advanced by various philosophers, for preferring pointed Conductors of lightning to such as are blunted, were confirmed ; but, however, that one remarkable observation, which could have been hardly believed before, was established, *viz.* that a point in those circumstances could receive so full a stroke, as we have mentioned above. Indeed this is a very good observation of Mr. WILSON, and a most plausible argument in favour of his opinion relating to the construction of the Conductors of lightning. Hence he expatiates upon the danger of those houses, which are furnished with elevated and pointed Conductors ; and absolutely recommends knobbed Conductors, which are either even with, or rather a little shorter, than the top of a building ; since, says he, the pointed Conductors invite the lightning. It is almost superfluous to remark, that

that it is for that very property, that elevated and pointed Conductors are preferable to knobbed ones, *viz.* because they attract the matter of lightning from a greater distance: hence they may defend a greater extent of building; hence, by drawing a considerable quantity of electric fluid from the clouds, when at a distance, so as to lessen their charge, they may thus actually avoid a full explosion; the intention of putting a Conductor to a house, being to defend the house from the bad effects of lightning, and not the Conductor itself from attracting the matter of, or being struck by, the lightning.—When the Conductor of a house is struck, the only damage it can receive in that case, it seems, can only arise from a lateral explosion between the Conductor and other pieces of metal, or other very good Conductors, which are contained in the house, and are not properly connected with the Conductor. For this reason, it is proper to connect with the Conductor, by a metallic communication, all the pieces of metal, and indeed other good Conductors, as a cistern of water, &c. that are in a house, especially those which are near the outside, and

and the top of it. This, however, is almost impossible to be done perfectly; but then those lateral effects are not of so very dangerous a nature, excepting indeed when the building contains substances of a very combustible quality, as gun-powder, &c. in which case, the most scrupulous attention is hardly sufficient to prevent any bad accident. Notwithstanding the obviousness of the above-mentioned remarks, Mr. WILSON's experiments determined several persons in favour of the knobbed Conductors: hence Mr. NAIRNE undertook to oppose Mr. WILSON's theory with a clear and convincing set of experiments. The prime Conductor used by Mr. NAIRNE was one foot in diameter, and six feet long, consequently by far smaller than that used by Mr. WILSON. The other apparatus was different, and the electrical machine was much more powerful than that used by Mr. WILSON *. But with this apparatus he amply shows the properties of points and knobs, with respect to Electricity; and, different from Mr. WILSON, shows, that in

* See Mr. NAIRNE's account of those Experiments, &c. in the 68th vol. of the Phil. Transf.

many experiments, and under various circumstances, a knob is struck in preference to a point. This diversity of appearances, and results of experiments, in cases seemingly alike, will at first sight be thought a contradiction; but, when duly considered, the different phenomena may be all reconciled to a few very simple and natural propositions. A point draws the electric fluid from an electrified body, from a much greater distance than a blunt-terminated body; but the quantity must be limited, and subject to be altered by many causes; such are, the degree of condensation of the electric fluid upon the electrified body; the time given to the point; the acuteness of the said point; its free or encumbered situation; its perfect or imperfect communication with the earth, &c. Thus, if the pointed body be not made to communicate with the earth, but the communication be interrupted by a short interval, then, on presenting a body sufficiently charged with electric fluid, to the said point, a full spark will go from the former to the latter, because the point, on account of the interruption of communication, cannot discharge

charge to the earth, or other fit body, the electric fluid by little and little, consequently cannot receive it silently from the electrified body to which it is exposed, but can attract only that quantity which can leap between the interruption, and which passes in the form of a spark. Thus also, if the point is suddenly brought within a sufficient distance of a strongly-electrified body, it will receive a spark, because a sufficient time was not allowed it to draw off the electric fluid silently, as would happen if the point was gradually brought near. After the same manner, the ingenious reader may imagine a great multiplicity of cases, in which a point may be struck or not struck by an electrified body; hence is derived the apparent contradiction between the experiments of Mr. HENLY, Mr. WILSON, Mr. NAIRNE, and various others: but it always remains true, that a pointed or sharp-edged body draws the electric fluid from a greater distance than those bodies which are blunt or more obtuse, all the other circumstances being the same in both cases.

Lord

Lord MAHON, in his above-mentioned work, shews a property of electric atmospheres, which he calls the *returning stroke*, and which he is of opinion that can occasion great damage in some cases. This is that quantity of electric fluid, which, by the vicinity of a cloud highly electrified, is driven away from certain bodies, and which suddenly returns to those bodies when the cloud happens to discharge its Electricity by a stroke of lightning to any other body ; for then the atmosphere which kept off the electric fluid of the bodies that were within its action, ceases at once. Our noble author shews experimentally, that such a returning stroke may occasion great damage, even at a good distance from the place where the stroke of lightning happens, and that its effects may be very considerable ; all which confirms the already-made observation, *viz.* that all the best and largest conducting bodies that are in a house, should be connected with the Conductor of lightning. Without detaining my reader with further disquisitions, I shall only take notice of the most notable particulars that should be kept in view,

and

and should be considered as the leading principles, in erecting Conductors for the lightning; and shall then conclude with the *requisites necessary* for the proper construction of Conductors, which requisites I shall transcribe exactly from Lord MAHON's work.

A pointed body attracts the matter of lightning more or less easily, according as it is more or less acute; according as it is less or more encumbered by surrounding bodies; or as it is more or less elevated, and as its communication with the earth, by means of conducting bodies, is more or less perfect. The clouds are bad Conductors, and in general the electric fluid is not highly concentrated on them in proportion to their extent; they are often separated from each other; they may come towards a Conductor or a house in every direction; and move with various velocities at different times. The pointed Conductor that is erected in order to transmit the lightning with safety to the ground, can only defend a limited extent of building, the quantity of which varies according to many circumstances.

stances. In cases of powder-magazines, and such-like very combustible substances, great damage may be occasioned by a lateral explosion or returning stroke, if the Conductor happened to be struck; which may be only avoided by making a proper communication between all the substances of a good conducting nature that are in the building. It has been observed that sometimes a stroke of lightning is branched, and strikes several objects at the same time.

In consequence of all those observations, and various others mentioned in the course of this book, it seems proper to have in view the following instructions, in erecting Conductors for the lightning.

1. "That the *rods* be made of such substances as are, in their nature, the best *Conductors* of Electricity."

2. "That the rods be *uninterrupted*, and perfectly *continuous*."

3. "That they be of a *sufficient thickness*."

4. "That they be perfectly *connected* with the *common-stock*."

5. "That the upper extremity of the rods be as *acutely pointed* as possible."

6. " That it be *very finely tapered*."

7. " That it be *prominent*."

8. " That each rod be carried, in the *shortest convenient direction*, from the point at its upper end, to the *common-stock*."

9. " That there be neither *large*, nor *prominent* bodies of metal upon the top of the building proposed to be secured, but such as are *connected with the Conductor* by some proper metallic communication."

10. " That there be a sufficient *number* of high and pointed rods : " And,

11. " That every part of the rods be *very substantially* erected."

N° III.

EXTRACT OF A LETTER FROM MR. ARDEN, LECTURER IN NATURAL PHILOSOPHY, DATED SEPTEMBER 25, 1772.

“ ABOUT fourteen or fifteen years ago, in the presence of WM. CONSTABLE, Esq; at his seat at Burton Constable, in Holderness, I made the following experiments :

“ I placed a large coated jar, that would hold three or four gallons, directly under the prime Conductor of a very good electrical machine. The prime Conductor was at least eight or ten inches above the top of the jar, and the communication was made by a brass wire, bent at one end over the prime Conductor, and the other end passed through a small glass tube (contrived by Mr. CONSTABLE to prevent the electric matter from easily flying off) was suspended in the middle of the jar, and had a small piece of brass chain fastened to it, that rested on the bottom of the jar.

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“ I then

“ I then began to turn the wheel, and after turning about 100 or 150 times, as low in the jar as I could see for the coating I perceived a ball of fire, much resembling a red-hot iron bullet, and full three quarters of an inch in diameter, turning round upon its axis, and ascending up the glass tube that contained the brass wire which was the Conductor to the inside of the jar.

“ I immediately asked Mr. CONSTABLE, if he saw the ball of fire? he said, Certainly. I said, I will turn on. He answered, By all means. I kept turning the wheel, and the ball of fire continued turning upon its axis, and ascending up the glass tube till it got quite upon the top of the prime Conductor. There it turned upon its axis some little time, and then gradually descended, turning upon its axis as it had done in its ascent, and so continued till it was so much below the top of the coating that we could no longer see it. Soon after this, a very great flash was seen, a large explosion was heard, and strong fumes of sulphur was perceived all over the room.

a room

round aperture was cut through the side of the jar, as fine as if it had been cut with a diamond, rather more than three quarters of an inch in diameter, and between two and three inches below the top of the coating, and the coating was torn off all round the aperture, about three or four inches in diameter. The jar was a pretty strong one, of crown glass.

“ I then took another jar, so like the first, that when both were whole I could not easily perceive any difference between them. I then attempted to charge this jar, in the same manner as the other, and we both observed it very accurately. No ball of fire was seen, but presently the jar discharged itself with a great flash and explosion, and at about the same part as of the first jar; but instead of the aperture which was made in the first jar, there was a circle about three quarters of an inch diameter, as white as chalk, and the coating torn off round about it as before. Upon touching the white part, it dropped out, and appeared to be glass in a fine powder.

Q₂

“ We

“ We broke several other different-sized jars that day, (which made Mr. CONSTABLE say we were in great luck) but without any thing else remarkable.

“ The first experiment was made soon in the afternoon of a clear day, and the machine stood directly between us and a window, which was not above a yard from it. I don't hear that this ball of fire has been produced by art by any one else, to this day, although it is often produced by nature.

“ I had the pleasure of seeing Mr. CONSTABLE this day, and of reading the account of these experiments to him, and, to the best of his memory, he thought the whole was strictly true.

“ Mr. CONSTABLE thinks it would not be difficult to repeat the experiment, and to produce the ball of fire at any time, provided the jar is large, and not coated too near the top, and that the wire communicating from the prime Conductor to the inside of the jar is made to pass through a small glass

glass tube, (which is certainly of great advantage in making experiments of this kind) and that the machine acts very strong. If not, it will be in vain to attempt it."

AFTER this letter, Dr. PRIESTLEY, out of whose works it has been transcribed, subjoins the following remarks * :—" The fact mentioned in the preceding letter is of a very remarkable nature, and, being perfectly well ascertained, it is of importance that it be generally known, and kept in view. For though no person, that has hitherto been made acquainted with it, has been able to repeat the experiment, others may be more fortunate. Dr. FRANKLIN, and, if I mistake not, Mr. CANTON also, and myself, were present when Mr. HENRY endeavoured to produce this appearance ; but, though every expedient that any of us could suggest was made use of, we had no success, and I have several times attempted it in vain since. I shall not, however, desist from my attempts."

* Experiments on Air, &c. vol. v.

“ Mr. ARDEN's own evidence is abundantly sufficient to authenticate the fact, and I have since had from Mr. CONSTABLE himself the same account of it. Could we repeat this experiment, there would not, I think, be any natural phenomenon, in which the electric fluid is concerned, that we could not imitate at pleasure. This circumstance alone makes it a very interesting object of investigation.”

N° IV.

OBSERVATIONS CONCERNING SOME PROPERTIES OF THE ELECTRIC FLUID.

AMONGST the various experiments performed by Mr. WILSON in the Pantheon, as mentioned in the preceding pages, he made some with a long wire, which was suspended by silk lines, and went in various directions through that great building. This wire was 4800 feet long, and $\frac{1}{4}$ of an inch in diameter. It consisted of many pieces, which were connected by twisting the several ends together. —Mr. WILSON electrified this extended wire by means of an electrical machine situated next to one of its extremities; and when the wire was fully charged, which happened after a few turns of the wheel, a person discharged it, by presenting his hand to it, which was attended with a short spark, but with a very disagreeable strong shock. Then Mr. WILSON took an equal length of wire, of the same diameter with

the above-mentioned extended one, and, putting it all coiled together upon a glass stand, charged it with electric fluid, by means of the same machine, and when this wire was fully charged, which took place after about half a turn of the wheel, a spark was taken from it, but which occasioned a sensation by no means comparable with that given by the extended wire, since this, though longer than the spark of the extended wire, was hardly to be felt, whereas that was remarkably strong.

The explanation of those effects might easily occur to a person little versed in Electricity. The extended wire acquired a much greater quantity of Electricity than that which was coiled up, for the same reason for which an extended piece of tin-foil, twenty square feet wide, and which weighs one pound, can acquire incomparably more Electricity than a solid ball of tin, which weighs one pound also; namely, because the extended wire exposes a far greater surface to the free air, than the wire that is coiled up; and the spark given by the coiled wire is longer than that given by

by the other, in so much as the electric fluid, whatever its quantity may be, can be much more condensed on the coiled than on the extended wire; it being well known, that the length of the spark given by electrified Conductors is proportional to the condensation, and not to the quantity of electric fluid.

To observe, that the extended wire required many turns of the wheel before it became charged, whereas the coiled wire required less than one turn; the observations made and mentioned by various writers on Electricity, relating to the capacity of Conductors under various circumstances; Dr. FRANKLIN's experiment of the *can* and *chain*, and innumerable other experiments of the like nature, might have convinced Mr. WILSON of the truth of the above-mentioned natural and clear explanation; but, upon those phenomena Mr. WILSON establishes a principle which does not seem satisfactory. He imagined, that in so much the extended wire gave a much stronger shock than that which was coiled up, as the electric fluid percurring the whole

whole length of the extended wire acquired a great degree of velocity ; hence the impetus with which it struck the hand or other body presented to the charged wire, occasioned that disagreeable sensation, which sensation was not accompanied with the spark given by the coiled wire, because the electric fluid could not acquire any velocity, as it did not go through a great extent of conducting substance.

This theory seems to be not true, for the following reasons. First, It is well known that metal, and in general any sort of conducting substance, does in some measure resist the free passage of the electric fluid through its substance ; hence the electric fluid, in going through a long Conductor, must be retarded rather than accelerated. Secondly, The electric fluid being elastic, whenever a way is open for it to escape out of a Conductor, upon which it has been confined, it must exert its greatest force at first ; that is, the quantity of it, which comes out at first, has the greatest velocity, because it is impelled by the greatest expansive force ; but, according as more and

more of the electric fluid comes out of the Conductor, that impelling force or elasticity lessens ; hence the last particles of electric fluid come out of the Conductor with less velocity ; thus in a condensing fountain, out of which the stream of water issues, on account of the elasticity of the air condensed in the cavity of the instrument, the stream at first comes out with greater violence, and mounts higher up, but afterwards loses its velocity by degrees, because the condensed air becomes gradually less and less condensed, and consequently exerts a force continually smaller and smaller against the water. Lastly, It may be observed in general, as it has been proved by many experiments, that if two unequal Conductors, one of which A is more extended than the other B, discharge equal quantities of electric fluid under the form of sparks from like terminations, the spark given by A is less strong than the spark given by B, and that for the above-mentioned reasons.

Notwithstanding the obviousness of those remarks, Mr. WILSON, since he first made the

the experiments at the Pantheon, seems to have become continually more and more attached to his opinion, so that some time ago, he published a small tract, entitled *A short View of Electricity*, in which he endeavours to establish his theory of the acceleration of the electric fluid, &c. upon mathematical principles. This step determined me to take notice of it in this Appendix, in order to prevent any wrong notions in the heads of novices; for persons who are not conversant with mathematics, will take any proposition for true, when they are assured that it is mathematically so. Mr. WILSON's theorem conceals a fallacy, and shews that a person very well skilled in a science, as Mr. WILSON is in Electricity, can easily fall into a mistake, when he is too much attached to a favourite opinion.—Mr. WILSON's words are the following:

“ Upon Acceleration.

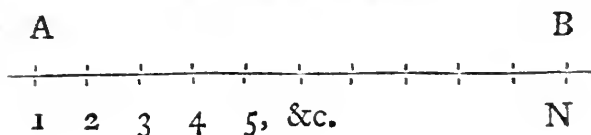
“ The experiments at the *Pantheon*,
 “ which were intended to shew the acce-
 “ leration of the fluid, having been object-
 “ ed to by many, who have not sufficiently
 “ attended

“ attended to the known properties of the
“ elastic fluid, it has been thought proper
“ here to establish this very material point
“ upon mathematical principles, with a
“ view to put an end to all farther dis-
“ putes on the subject.

“ But before this is done, it may be
“ necessary to mention a material fact that
“ was omitted in the account of those ex-
“ periments ; which is this,

“ The shock received at the *middle* of
“ the long wire, was *considerably* less than
“ that which was received at either end.

“ T H E O R E M.



“ Let A B represent a cylinder of a given
“ diameter, and suppose this cylinder
“ charged with the electric fluid. I say,
“ if all the particles of this fluid are moved
“ at the same instant towards A, the effect
“ produced by the shock of this fluid at
“ A will

“ A will be nearly proportional to the
 “ square of A B ; for the total effect at
 “ A is equal to the sum of the effect of each
 “ particle contained in the cylinder A B :
 “ and the effect of each particle being pro-
 “ portional to its velocity, the total effect
 “ at A will be proportional to the sum of
 “ all the velocities. But since the fluid is
 “ supposed nearly perfectly elastic, all the
 “ particles will arrive at A nearly at the
 “ same instant ; then the velocity of each
 “ particle will be proportional to the dis-
 “ tance from the place it sets out, and the
 “ total effect at A will be proportional to
 “ the sum of all those distances.

“ But all those distances are expressed
 “ by the following numbers, 1, 2, 3, 4, 5,
 “ &c. - - - - - N (N expressing the
 “ length A B) in an arithmetical progres-
 “ sion. Then the sum of all the distances
 “ will be expressed by the sum of the
 “ arithmetical progression 1, 2, 3, 4, 5,
 “ &c. - - - - - N, and the effect at A
 “ will be proportional to this sum, that is
 “ to say, to N^2 or AB^2 . Q. E. D.”

Mr.

Mr. WILSON's abstract proposition is certainly evident, *viz.* "That if all the particles of the electric fluid are moved at the same instant towards A, (by which, I suppose, he means if they arrive at A in the same instant of time) the effect produced by the shock of this fluid at A will be nearly proportional to the square of A B." But this proposition cannot be possibly applied to the matter of fact, or actual experiment, since the condition upon which the proposition depends cannot be verified; *viz.* we do not know whether or no the particles of the electric fluid that are in the long wire, do all arrive at one end of it precisely at the same time. Besides, we may safely say, that from the considerations mentioned in the preceding pages, and from the analogy of other natural phenomena, it appears that they do not, and cannot arrive to the extremity of the wire precisely at the same time. Between the particles of electric fluid which arrive first at one extremity of the wire, and those which arrive last at the same extremity, there is an interval, a difference of time. Mr. WILSON says, "all the particles will arrive at A, nearly

A, *nearly* at the same instant." Now, even that *nearly* implies a length of time, which, however imperceptible it may be to our senses, is yet sufficient for the natural operation. For instance, suppose that the extended and electrified wire is a mile long, and also suppose that a quantity of electric fluid employs one hundredth part of a second of time to go through that length of wire, and that without acceleration, or even with a little retardation, which is by no means an exaggerated supposition. Now, if a way be opened to the electric fluid in the wire, *viz.* the hand, &c. be presented to one extremity of it, the nearest particles of the electric fluid will come out first, and the remotest last; yet that difference, agreeably to the supposition, does not exceed one hundredth part of a second, which is absolutely unperceivable by our senses; so that the appearance is exactly the same as if all the particles of the electric fluid came out of the extremity of the wire precisely at the same instant of time. I think, therefore, that what Mr. WILSON imagines to have established upon mathematical principles, is far from being mathematically demonstrable. Without dwelling
any

any longer upon Mr. WILSON's proposition, and the corollaries which he deduces from it, I shall only take notice of a remarkable experiment he made at the Pantheon, with the already-mentioned apparatus; which, however, he attributes to the accumulated velocity, which the electric fluid acquired in percurring the substance of a very long Conductor.

Mr. WILSON fired gunpowder by means of the stream of electric fluid, but without spark or shock. The method is as follows, in his own words: " Upon a staff of baked
" wood a stem of brass was fixed, which
" terminated in an iron point at the top.
" This point was put into the end of a
" small tube of Indian paper, made somewhat in the form of a cartridge, about
" two-tenths of an inch in diameter.
" When this cartridge was filled with
" common gunpowder (unbruised) the
" wire of communication with the well
" was then fastened to the bottom of the
" brass stem. Being so circumstanced, and
" whilst the charge in the great cylinder
" and wire was continually kept up by
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“ the motion of the wheel, the top of the
 “ cartridge was brought so near to the
 “ drums as frequently to touch the metal.
 “ In this situation, a small, faint, lumi-
 “ nous stream was observed between the
 “ top of the cartridge and the metal
 “ drum.

“ Sometimes this stream would set fire
 “ to the gunpowder at the instant of the
 “ application; at others, it would require
 “ half a minute, or more, before it took
 “ effect. But this difference in time
 “ might probably arise from some differ-
 “ ence in the circumstances; for any the
 “ least moisture, &c.”

It seems that in this experiment the gun-
 powder was fired by the heat occasioned
 by the dense stream issuing out of the vast
 Conductor, which discharged a prodigious
 quantity of electric fluid in that concen-
 trated manner. This experiment was af-
 terwards imitated by Mr. NAIRNE, with
 the Leyden phial. When a large electric
 jar was charged, Mr. NAIRNE presented
 the cartridge of gunpowder, similar to that

used by Mr. WILSON, to the knob of the jar, and the powder was fired without any explosion of the jar. In this experiment, the wire upon which the cartridge was fixed, did not communicate with the outside of the jar by a good conducting communication, but both the outside of the jar, and the said wire, did communicate with the ground; so that it may be said, that the circuit between the two sides of the jar was imperfect; hence the discharge was not made by a full explosion:

N°. V.

EXTRACTS FROM MR. VOLTA'S PAPER,

Inserted in the 72d vol. of the Phil. Transf.

Concerning the Capacity of Conductors, a new Method of discovering very small Degrees of Electricity, and the Electricity of the Atmosphere.

MR. VOLTA'S paper on the method of discovering the smallest degrees of Electricity, either natural or artificial, containing several particulars not only new, but also very interesting to electricians, it was deemed necessary to insert in this book at least a summary account of them ; and had the limits of the work permitted it, I should have transcribed the whole paper ; however, the extracts are such as, I imagine, will convey a distinct idea of the discoveries of that excellent electrician, and will leave out no more than what the ingenuity of the reader may easily supply. I have generally used the
word

words of Mr. VOLTA himself; but I have changed in great measure the order of the paragraphs, for the sake of rendering the subject more intelligible in a contracted state.

Conducting bodies, of the same shape, will contain a greater or less quantity of Electricity, according as their surfaces are less or more influenced by *homologous atmospheres*; and the capacity of a Conductor, which has neither its form nor surface altered, is increased when, instead of remaining quite insulated, the Conductor is presented to another Conductor not insulated, and this increase is more conspicuous, according as the surfaces of those Conductors are larger and come nearer to each other.—When an insulated Conductor is opposed or presented to another Conductor whatever, Mr. VOLTA calls it a *conjugate Conductor*.

In order to shew by experiment the above-mentioned property or increase of capacity in a Conductor, take the metal plate of an electrophorus, and holding it by its insulating handle in the air, electrify it so high, as that the index of an electrometer an-

nexed to it might be elevated to 60° ; then lowering this metal plate by degrees towards a table or other conducting plain surface, you will observe that the index of the electrometer will fall gradually from 60° to 50° , 40° , 30° , &c. Notwithstanding this appearance, the quantity of Electricity in the plate remains the same, except the said plate be brought so near the table as to occasion a transmission of the Electricity from the former to the latter; at least the quantity of Electricity will remain as much the same as the dampness of the air, &c. will permit. The decrease, therefore, of intensity is owing to the increased capacity of the plate, which is now *conjugate*, viz. opposed to another conducting surface. In proof of which, remove gradually the metal plate from the table, and it will be found that the electrometer rises again to its former station, namely to 60° , excepting the loss of that quantity of Electricity, which during the experiment must have been imparted to the air.

The reason of this phenomenon is easily derived from the action of electric atmospheres.

spheres. The atmosphere of the metal plate, which, for the present, we shall suppose to be electrified positively, acts upon the table or other Conductor to which it is presented; so that the electric fluid of the table, agreeably to the known laws, retiring to the remoter parts of it, becomes more rare in those parts which are exposed to the metal plate, and this rarefaction becomes greater, the nearer the electrified metal plate is brought to the table. If the metal plate is electrified, then the contrary effects must take place. In short, the parts immersed into the sphere of action of the electrified metal plate, contract a contrary Electricity, which *accidental* Electricity, making in some manner a compensation for the *real* Electricity of the metal plate, diminishes its intensity, as is shewn by the depression of the electrometer.

The two following experiments will throw more light upon the reciprocal action of the electric atmospheres. First, suppose two flat Conductors, electrified both positively or both negatively, to be presented towards, and to be gradually brought near,

each other ; it will appear by two annexed electrometers, that the nearer those two Conductors come to each other, the more their intensities will increase ; which shews, that either of the two *conjugate* Conductors has a much less capacity now, than when it was singly insulated, and out of the influence of the other. This experiment explains the reason why an electrified Conductor will shew a greater degree of intensity when it comes to be contracted into a smaller bulk ; and also why a long extended Conductor will shew a less degree of intensity than a more compact one, supposing that the quantity of surface and of Electricity is the same in both ; because the homologous atmospheres of their parts interfere less with each other in the former than in the latter case.

Secondly, let the preceding experiment be repeated, with this variation only, *viz.* that one of the flat Conductors be electrified positively, and the other negatively : the effects then will be just the reverse of the preceding ; *viz.* the intensities of their Electricities will be diminished, because
their

their capacities are increased, the nearer the Conductors come to each other.

Let us now apply the explanation of this last experiment to that of bringing an electrified metal plate towards an uninsulated conducting plane; for as this plane acquires a contrary Electricity by the vicinity of the electrified plate, it follows that the intensity of the Electricity of the metal plate must be diminished, and in the same proportion its capacity is increased; consequently the metal plate in that case may receive a greater quantity of Electricity.

This property may be rendered still more evident, by insulating the conducting plane whilst the electrified plate is very near it, and afterwards separating them; for then both the metal plate and the conducting plane (which may be called the *inferior* plane) will be found electrified, but possessed of contrary Electricities, as may be ascertained by electrometers,

If the inferior plane be insulated first, and then the electrified plate be brought over it,
then

then the latter will cause an endeavour in the former to acquire a contrary Electricity, which however the insulation prevents from taking place; hence the intensity of the Electricity of the plate is not diminished, at least the electrometer will shew a very little and almost imperceptible depression, which is owing to the imperfection of the insulation of the inferior plane, and to the small rarefaction and condensation of the electric fluid, which may take place in different parts of the said inferior plane. But if in this situation the inferior plane be touched, so as to cut off the insulation for a moment, then it will immediately acquire the contrary Electricity, and the intensity in the metal plate will be diminished.

If the inferior plane, instead of being insulated, were itself a non-conducting substance, then the same phenomena would happen, *viz.* the intensity of the electrified metal plate laid upon it would not be diminished. This, however, is not always the case; for if the said inferior non-conducting plane be very thin, and be laid upon a Conductor, then the intensity of the electrified
metal

metal plate will be diminished, and its capacity will be increased by being laid upon the thin insulating stratum; because in that case the conducting substance, which stands under the non-conducting stratum, acquiring an Electricity contrary to that of the metal plate, will diminish its intensity, &c. and the insulating stratum will only diminish the mutual action of the two atmospheres, more or less, according as it keeps them more or less asunder.

The intensity or electric action of the metal plate, which diminishes gradually as it is brought nearer and nearer to a conducting plane not insulated, becomes almost nothing when the plate is nearly in contact with the plane, the compensation or accidental balance being then almost perfect; hence if the inferior plane only opposes a small resistance to the passage of the Electricity (whether such resistance be occasioned by a thin electric stratum, or by the plane's imperfect conducting nature, as is the case with dry wood, marble, &c.) that resistance, and the interval, however small, that is between the two planes, cannot be overcome

come by the weak intensity of the Electricity of the metal plate, which on that account will not dart any spark to the inferior plane (except its Electricity were very powerful, or its edges not well rounded) and will rather retain its Electricity; so that, being removed from the inferior plane, its electrometer will nearly recover its former height. Besides, the electrified plate may even come to touch the imperfectly conducting plane, and may remain in that situation for some time: in which case the intensity being reduced almost to nothing, the Electricity will pass to the inferior plane exceedingly slowly.

But the case will not be the same, if, in performing this experiment, the electrified metal plate be made to touch the inferior plane *edgewise*; for then its intensity being greater than when laid flat, as it appears by the electrometer, the Electricity easily overcomes the small resistance, and passes to the inferior plane, even across a thin electric stratum; because the Electricity of one plane is balanced by that of the other, only in proportion to the quantity of surface

face which they oppose to each other within a given distance; whereby, when the metal plate touches the other plane in flat and ample contact, its Electricity is not dissipated.

This explanation, properly applied, renders evident the action of *points* in general. Justly speaking, a pointed Conductor, not insulated, when presented to an electrified body, has not in itself any particular virtue of attracting Electricity. It acts only like a Conductor not insulated, which does not oppose any resistance to the passage of the electric fluid. If the same Conductor, instead of being pointed, were to present a globular or flat surface to the electrified body, neither in that case it would oppose a greater resistance to the passage of the Electricity. But the reason why the Electricity will not pass nearly so easily from the electrified body to the globular or flat conductor, as to the pointed one, is because in the former case the intensity of the Electricity in the electrified body is weakened by the opposed flat surface, which, acquiring the contrary Electricity, compensates the diminished

minished intensity incomparably more than a point is able to do. It appears, therefore, that it is not the particular property of a point or of a flat surface, but the different state of the electrified body, that makes it part with its Electricity easier, and from a greater distance, when a pointed conducting substance, than when a flat globular one, is presented to it.

What looks like a paradox in the case of an electrified plate standing upon an imperfectly conducting plane, is, that the metal plate, whilst standing upon the other plane, will not lose all its Electricity, even if it be touched with a finger or with a piece of metal; so that it generally remains so far electrified, as when it is afterwards separated from that plane, it will often afford a small spark, or at least it will affect an electrometer. Indeed this phenomenon could not be explained upon the supposition that the finger or the metals were perfect Conductors: but since we do not know of any perfect Conductor, the metals or the finger oppose a resistance sufficient to retard the immediate dissipation of the Electricity
of

of the plate, which is in that case actuated by a very small degree of intensity or endeavour of expanding ; so that suppose, for instance, that the piece of metal or the finger, by touching the plate, took off so much of its Electricity as to reduce the intensity of the remainder to the fiftieth part of a degree, this remaining Electricity would then be almost nothing ; but when the plate, by being separated from the inferior plane, has its capacity so far diminished as to render the intensity of its Electricity one hundred times greater, then the intensity of that remaining Electricity would become of two degrees, *viz.* sufficient to afford a spark or to affect an electrometer.

Hitherto we have considered in what manner the action of electric atmospheres must modify the Electricity of the metal plate in various situations. We must now consider the effects which take place when the Electricity is communicated to the metal plate whilst standing upon the imperfectly conducting plane ; however the explanation of this easily follows from what has been said above. Suppose, for instance, that a
Leyden

Leyden phial or a Conductor were so weakly electrified, that the intensity of its Electricity were only of half a degree, or even less ; if the metal plate, when standing upon the proper plane, were touched with that phial or Conductor, it is evident that either of them would impart to it a quantity of its Electricity, proportional to the plate's capacity, *viz.* so much of it as would make the intensity of the Electricity of the plate equal to that of the Electricity in the Conductor or phial, supposed of half a degree ; but the plate's capacity, now that it lies upon the proper plane, is above one hundred times greater than if it stood insulated in the air ; or, which is the same thing, it requires one hundred times more Electricity in order to shew the same intensity ; therefore, in this case, it must acquire upwards of a hundred times more Electricity from the phial or Conductor. It naturally follows, that when the metal plate is afterwards removed from the proper plane, its capacity being lessened so as to remain equal to the hundredth part of what it was before, the intensity of its Electricity must become of 50° ; since, agreeably to the supposition, the
intensity

intensity of the Electricity in the phial or Conductor was of half a degree*.

A Conductor that is electrified whilst standing in full and ample contact with another proper Conductor, or semi-insulating body, as above mentioned, and is afterwards separated from it, shews the same phenomena that are exhibited by a Conductor, which, after being electrified, is contracted into a smaller bulk, or contrarywise, like Dr. FRANKLIN's experiment of the can and chain, &c. †.

If a small quantity of Electricity communicated to the metal plate, whilst stand-

* In a paper on the capacity of simple Conductors, Mr. VOLTA, considering the great capacity of a Leyden phial, shews that the cause of it is the Electricity communicated to one of its surfaces being balanced by the contrary Electricity of the opposite surface. He likewise proves, that the capacity of sixteen square inches of coated electric surface is equal to the capacity of a Conductor made of silvered cylindrical sticks, nearly one hundred feet long, the capacity of which is so great as to afford a spark capable of occasioning a shock considerably strong.

† See page 331, vol. i. of this work,

ing on the proper plane, will afterwards enable it to give a strong spark, it may be asked, what would a great quantity of Electricity do? The answer is, that it would do nothing more; because, when the Electricity communicated to the metal plate is so strong as to overcome the small resistance of the inferior plane, it will then be dissipated.

It will be readily understood, that if the metal plate situated upon a proper plane can receive a good share of Electricity from a Leyden phial, or from an ample Conductor, however weakly electrified, it cannot receive any considerable quantity of it from a Conductor of a small capacity; for this Conductor cannot give what it has not, except it were continually receiving a stream, howsoever small, of Electricity, as is the case with an atmospherical Conductor, or with the prime Conductor of an electrical machine, which acts very poorly, but continues in action. However in such case a considerable time must elapse before the metal plate has acquired a sufficient quantity of Electricity.

Thus

Thus much being premised relating to the capacity of Conductors, we now proceed to describe Mr. VOLTA's ingenious method of discovering, or of rendering sensible, the smallest quantity of Electricity, which is entirely dependant on the foregoing principles.

The method, in short, is to communicate the small, and otherwise unobservable quantity of Electricity, to the metal plate of an electrophorus whilst standing on an imperfectly insulating plane; for in that situation the capacity of the metal plate being augmented, it will acquire an incomparably greater quantity of Electricity than if it stood insulated in the air; and afterwards, when separated from the plane, its capacity will be contracted; and consequently, its Electricity increasing at the same time, its intenseness will evidently manifest itself either by sparks, or, which is the easiest and safest method, by affecting an electrometer.

The particulars necessary to be kept in view in this method are the following. The metal plate must be at least six inches in di-

ameter, with the edge well rounded, and having a varnished glass handle;—instead of a glass some persons have used three silk strings. The inferior plane must be of a very imperfect conducting nature, as dry marble, very dry and slightly varnished wood, a common piece of wood covered with oiled silk, or such-like substance; but let the substance be what it will, its surface must be very smooth, and such as to coincide as well as possible with the surface of the metal plate; on which account, if a marble slab be chosen for the inferior plane, it will be proper to fit the surface of the metal plate to that of the marble, by grinding one against the other. What I find to be very fit for this purpose is a paper drum, consisting of a common wooden hoop, such as are used for casks, over which a piece of thick writing-paper is pasted, on the back of which I paste a piece of tin-foil. The upper surface of the paper is varnished only once with shell-lac dissolved in spirit of wine. This sort of plane has many advantages, *viz.* it is easily made, and being light is very portable; its surface is perfectly plane, excepting indeed when the
hoop

hoop is not very strong, for then the contraction of the paper has power sufficient to warp it ; and lastly, as the thickness of the paper and of the varnish may be varied at pleasure, and very easily, the said plane may be rendered of any required degree of conducting power.

Now supposing that an inferior semi-conducting plane and a metal plate are properly constructed, lay the former upon a table, and upon it lay the latter, taking care that in this operation, or in wiping, &c. the surface of the inferior plane be not excited, for that would frustrate the experiment*. Then, with the corner of a dry handkerchief, a piece of flannel, of paper, &c. strike five or six times the metal plate. Afterwards, laying hold of the glass handle, lift up the metal plate from over the inferior plane, and presenting it to the electrometer you will find that it is evidently electrified. If

* In case the surface of the inferior plane has acquired any Electricity, either from rubbing it inadvertently, or otherwise, the best way of freeing it of that Electricity, is to pass it over the flame of a candle two or three times.

this experiment of striking the plate be repeated when the plate is not on the proper plane, you will find either not the least vestige of Electricity, or a quantity of it incomparably smaller than that obtained in the other way .

By this means, Mr. VOLTA has obtained Electricity not only sufficient to manifest its quality, but even enough to afford sparks, and that from substances which could be hardly suspected to be electrified. An atmospherical Conductor not much elevated above the top of a house, if it be made to communicate with the metallic plate standing on the proper plane (which Mr. VOLTA justly calls the *electrical condensing apparatus*) will be found to be electrified at times in which it would not shew any signs of Electricity by any other means. Several substances, even some that are considered as very good Conductors, will be found to afford a sensible quantity of Electricity, when the metal plate of the condensing apparatus is stroked with any of them, such as pieces of cloth, or of leather, moist green vegetables, and even the human hand,

hand. Indeed there is hardly any substance, besides fluids or very soft substances, which will not afford a sensible degree of Electricity by this method. But the most remarkable discoveries made by Mr. VOLTA, are that the evaporation of water and other fluids produces Electricity. Some effervescences he also found to produce Electricity, though their Electricity may be only the consequence of the evaporation which generally accompanies effervescences; but before I mention any thing farther relating to those discoveries, I shall just describe two improvements of mine concerning the above-mentioned condensing apparatus.

Observing that in stroking the metal plate in order to obtain Electricity from various substances, and especially from the hand, the plate was often moved so as to occasion some friction upon the inferior plane, which sometimes excited that plane in a small degree, and consequently rendered precarious the result of the experiment, I thought of the following improvement, which entirely prevents any motion being communicated to the metal plate.

Upon a varnished glass handle a brass tube about six inches long, and $\frac{3}{4}$ of an inch in diameter, was cemented, and from the extremity of this tube a fine and very flexible wire proceeded, which was about fourteen inches long. Now when the metal plate was situated upon the inferior plane, I held the glass handle of the brass tube with my left hand, in such a manner as that the end of the wire might touch the plate, the rest remaining in the air. Sometimes, in order to make a better contact, the end of the above-mentioned wire was put into a hole purposely made in the edge of the plate. In this disposition of the apparatus the substances to be tried are stroked upon the brass tube, and the Electricity produced by them is conveyed to the metal plate by the wire, which being fine and flexible communicates not the least motion to the said plate.

The other improvement consists in rendering sensible degrees of Electricity still smaller than those, which may be discovered by the above-mentioned condensing apparatus. This improvement was suggested by, and is founded upon, the same principles,

Notwithstanding the great sensibility of this apparatus of Mr. VOLTA, yet sometimes the Electricity acquired by the metal plate from some substances, was so small as not to affect an electrometer sufficiently to ascertain its quality, or even its existence; hence I naturally thought that, for the same reason for which the metal plate of the condensing apparatus manifested such small degrees of Electricity as could not be otherwise observed, another smaller plate, or small condensing apparatus, might be employed to collect and render sensible the weak Electricity of the large metal plate. Accordingly I constructed a small plate of about the size of a shilling, having a glass handle covered with sealing-wax; and when the large metal plate seemed to be so weakly electrified as not to affect an electrometer sensibly, I placed the small plate upon the inferior plane, and touched it with the edge of the large plate: then, after removing the large plate, I took up the small one from the plane, holding it by the extremity of the glass handle, and presented it to the electrometer; which was generally so much affected by it as to diverge to its utmost limits.

In

In this manner I have often obtained Electricity more than sufficient to ascertain its quality, from a single stroke of the corner of a handkerchief: *viz.* the large plate being placed upon the proper plane was stroked once; then being removed and presented to an electrometer, it appeared not electrified, but by touching the small plate with the edge of it, that small plate acquired thereby Electricity sufficient to make an electrometer diverge.

When this secondary condensing apparatus is used, care must be had to hold the large plate almost vertically whilst the small plate is touched with it. There is no need of having another inferior plane for the small plate, the large one being sufficient for both; for immediately after taking up the large plate weakly electrified, with one hand, you lay down the small plate, &c.

The little quantity of Electricity that can be discovered by this means is really surprising; and there is hardly any substance, excepting the metals, or those which cannot be
subjected

subjected to trial, as water and other fluids, which will not produce some Electricity when rubbed or stroked against the large plate of the condensing apparatus, and that Electricity is afterwards condensed by being communicated to the small plate. In consequence of those experiments it appears, that throughout the works of nature there is a continual motion of the electric fluid from one substance to another; since there is hardly any friction, and, as it will appear by what follows, any evaporation or condensation, but it produces Electricity. The extensive influence of this fluid, or of that power which we call *electric*, and the immense dependence of the powers of nature on each other, indicate that Electricity must be employed for some great operation; but human industry has not yet removed the veil from this great mystery.

The principal discovery, which Mr. VOLTA made by means of the condensing apparatus, is the Electricity produced by the evaporation of water, which explains in a great measure, if not entirely, the origin of
the

the atmospherical Electricity*. He found that water quickly evaporated, that the simple combustion of coals, and that the effervescence of iron filings, in diluted vitriolic acid, when performed in insulated vessels, left the vessels negatively electrified. This negative Electricity he generally collected and rendered manifest by means of the above-described condensing apparatus; but sometimes it is so strong as not to require any thing more than a sensible electrometer connected with the insulated vessel by means of Conductors, as a wire or the like.

The experiment of producing Electricity by the evaporation of water may be easily performed, thus:—Upon an insulating stand, as a wine glass or other electric substance, place an earthen vessel, as a crucible, a basin, or such like thing, and put into it three or four lighted coals. Let a wire be put with one end amongst the coals, and with the other let it touch a very sensible electrometer. (One of my improved atmo-

* This discovery was made on the 13th of April, 1782.

spherical electrometers, *viz.* that in the bottle, answers very well.) Then pour a spoonful of water at once upon the coals, which will occasion a great hissing, and a quick evaporation ; and at the same time you will see the electrometer diverge with negative Electricity.

Mr. VOLTA concludes the account of those discoveries with the following ingenious remarks. “ The experiments,” *says he*, “ hitherto made, though not numerous, yet concur to shew, that the vapours of water, and in general the parts of all bodies, that are separated by volatilization, carry away an additional quantity of electric fluid as well as of elementary heat ; and consequently that those bodies, from the contact of which the volatile particles have been separated, remain both cooled and electrified negatively : from which it may be deduced, that whenever bodies are resolved into volatile elastic fluid, their capacity for holding electric fluid is augmented, as well as their capacity for holding common fire, or the calorific fluid. This is a striking analogy
“ by

“ by which the science of Electricity
“ throws some light upon the theory of
“ heat, and alternately derives light from
“ it.

“ By following this analogy it seems,
“ that as the vapours on their condensing
“ lose part of their latent heat, on account
“ of their capacity being diminished, so
“ they part with some electric fluid. Hence
“ originates the positive Electricity, which
“ is always more or less predominant in the
“ atmosphere, when the sky is clear, *viz.*
“ at that height where the vapours begin
“ to be condensed. Accordingly, the at-
“ mospherical Electricity is stronger in fogs,
“ in which case the vapours are more con-
“ densed, so as to be almost reduced into
“ drops, and is still stronger when thick
“ fogs become clouds.

“ Hitherto we have accounted for the
“ positive atmospherical Electricity ; but it
“ is easy to account for clouds negatively
“ electrified ; for when a cloud, positively
“ electrified, has been once formed, its
“ sphere of action is extended a great way
“ round,

“ round, so that if another cloud comes
 “ within that sphere, its electric fluid,
 “ agreeably to the well-known laws of
 “ electric atmospheres, must retire to the
 “ parts of it which are the remotest from
 “ the first cloud ; and from thence the
 “ electric fluid may be communicated to
 “ other clouds, or vapours, or terrestrial
 “ prominencies. Thus a cloud may be
 “ electrified negatively, which cloud, after
 “ the same manner, may occasion a positive
 “ Electricity in another cloud, &c. This
 “ explains not only the negative Electricity,
 “ which is often obtained from the atmo-
 “ sphere in cloudy weather, and the fre-
 “ quent changes from positive to negative
 “ Electricity, and contrarywise in stormy
 “ weather, but also the waving motion
 “ often observed in the clouds, and the
 “ hanging down of them, so as nearly to
 “ touch the earth.

“ After the fore-mentioned discoveries,
 “ we need no longer wonder at the appear-
 “ ance of lightnings in the eruptions of vol-
 “ canos, as was particularly observed in the
 “ late

“ late dreadful eruption of Mount Vesuvius.
“ The few experiments I have made, shew
“ that the quantity of smoke, but much
“ more the rapidity with which it is pro-
“ duced, tends to increase the Electricity,
“ which arises from combustion, &c. How
“ great must then be the quantity of Elec-
“ tricity that is produced in such erup-
“ tions ! ”

N^o VI.

AN ACCOUNT OF A VERY POWERFUL
ELECTRICAL MACHINE, LATELY CON-
STRUCTED FOR THE MUSEUM OF TEY-
LER, AT HARLEM; AND OF VARIOUS
EXPERIMENTS MADE WITH IT.

TH E description of this machine, and of several experiments made with it, was written by Mr. VAN MARUM, who has himself been the principal operator in those experiments. The various new and interesting particulars which are mentioned in this description, render it deserving of being read at large by every lover of philosophy; and the present short extract is intended only to give an idea of it to those who have not the opportunity of perusing the original, which was lately published at Harlem.

This machine consists of two circular glass plates, each 65 inches in diameter, which being fixed parallel to each other, and

$7\frac{1}{2}$ inches asunder, on a common axis, are turned by a winch without any accelerated motion, and are rubbed by eight rubbers, all being placed in a proper frame. Each plate is rubbed on both surfaces; two cushions or rubbers being on one side, and two on the opposite side of each plate. The prime Conductor is divided into branches, which enter between the plates, and, by means of points, collect the electric fluid only from their inner surfaces.

In general two men are employed to work this machine, but when it is required to keep it in action for a long time, then four men are put to it.

The power of this machine appears to be greater than that of any other made before, and indeed its effects are surprising. I shall only enumerate them as briefly as possible, without expatiating on the points of comparison between them and others of a similar nature, performed with other machines.

A very sharp steel point, being presented to the prime Conductor, drew a luminous stream

stream of electric fluid, about half an inch long.

When a sharp steel point was fixed to the Conductor, so as to project three inches from it, on working the machine the point threw out streams of light, which were six inches long when a ball of three inches in diameter was presented to it, and only two inches long when another point was presented instead of the ball.

The sensation, commonly called the spider's web, on the face of the by-standers, when this machine is in action, is often felt at the distance of eight feet from the prime Conductor.

A thread six feet long, suspended perpendicularly, was sensibly attracted by the prime Conductor at the distance of thirty-eight feet. This attraction of the thread by the prime Conductor was such as just to make the thread deviate from the perpendicular direction. A pointed wire, presented to the Conductor, appeared luminous, even when the distance between the former and the latter was twenty-eight feet.

Another Conductor being presented to the prime Conductor, in order to receive the sparks from it, and a perfect metallic communication being made between the former and the earth, by means of a long brass wire $\frac{3}{8}$ of an inch in diameter; it was found, that whilst a stream of electric fluid went from the prime Conductor to the other, which may be called the *receiving Conductor*, the brass wire gave small sparks to conducting bodies that were placed near it. The quantity of electric fluid, accumulated by this machine and discharged by the prime Conductor, must have been really surprisngly great; since a wire of $\frac{3}{8}$ of an inch in diameter was not capable of transmitting it to the earth very easily. The sparks between the two Conductors were generally 21, but sometimes 24 inches long. The stream of fire was crooked, and darted many lateral brushès of a very large size.

Gunpowder, after the manner formerly used by Mr. WILSON, as it is mentioned in the preceding pages, and some other combustibles, could be fired at the prime Conductor of this machine.

A single

A single spark from the Conductor melted a considerable length of gold-leaf.

A Leyden phial, containing about one square foot of coated surface, was fully charged by about half a turn of the winch, so as to discharge itself; and by repeated trials it was found, that in one minute's time this phial discharged itself 76, 78, and often 80 times.

By many repeated experiments, accurately made by Mr. VAN MARUM, and other ingenious persons, with this machine, it was found, that electrization, whether positive or negative, did neither sensibly augment nor diminish the natural number of pulsations in a man *.

They

* In my Essay on Medical Electricity it is mentioned, that from the experience of many it appeared, that Electrization increases the number of pulsations about one sixth; but having made several experiments upon myself, I added the following observation in the second edition of the said Essay, which was published in the year 1781, and consequently long before Mr. VAN MARUM's experiments. " I do not remember that " my pulse was ever evidently accelerated by electri-

They wished to try the effect of taking the electric sparks in different sorts of elastic fluids, and for this purpose, they used a cylindrical glass receiver, five inches long, and an inch and a quarter in diameter, into which different sorts of elastic fluids were successively inserted, and were confined by quicksilver or water. To a hole made in the bottom of the inverted glass receiver an iron wire was fastened, the external part of which communicated with a Conductor, which, being presented to the prime Conductor of the machine, received the sparks from it. In this disposition of the apparatus it evidently appears, that the sparks passed through the elastic fluid contained in the receiver, by going from the inner extre-

“ zation, and yet I have repeated the experiment va-
 “ rious times, and with great diversity of circumstan-
 “ ces.” P. 15.—Upon the whole therefore it seems to be ascertained, that electrization does not accelerate nor retard the ordinary number of pulsations, and that the augmentation generally observed before must have been owing to fear or apprehension. But I am informed by Mr. PARTINGTON, who has long practised medical Electricity, that electrization, if not in a sound, at least in an unsound state of the body, augments the number of pulsations considerably.

mity of the wire to the quicksilver or water in which the receiver was inverted. With this apparatus it was found, that dephlogisticated air, obtained from mercurial red precipitate, lost $\frac{1}{10}$ of its bulk, but its quality was not sensibly altered, as it appeared from examining it with the eudiometer. This experiment being repeated when the receiver was inverted in lime-water, and likewise in the infusion of turnsole, there ensued no precipitation, no change of colour, nor any phlogistication of the air. On pouring on this air, the usual smell of the electric fluid was perceived very sensibly.

Nitrous air was diminished of more than the half of its original bulk, and in that diminished state, being mixed with common air, it occasioned no red colour, nor any sensible diminution. It had lost its usual smell, and it extinguished a candle. In passing the sparks through the nitrous air, a powder is formed on the surface of the quicksilver, which is a part of that metallic substance dissolved by the nitrous acid.

Inflammable air, obtained from iron and

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diluted

diluted vitriolic acid, communicated a little redness to the tincture of turnsole. The stream of electric fluid through this air appeared more red, and much larger, than in common air, being every where surrounded by a faint blue light.

The inflammable air, obtained from spirit of wine and vitriolic acid, was increased to about three times its original bulk, and lost a little of its inflammability.

Fixed air, from chalk and vitriolic acid, was a little increased in bulk by the action of Electricity; but it was rendered less absorbible by water.

Vitriolic acid air, obtained from vitriolic acid and charcoal, was diminished a little, and black spots were formed on the inside of the glass receiver. Afterwards it was observed, that only one eighth part of the electrified elastic fluid was absorbed by water. It extinguished a candle, and had very little smell.

Marine acid air seemed to oppose in great measure

measure the passage of the electric fluid; since the sparks would not pass through a greater length than $2\frac{1}{4}$ inches of this air. It was considerably diminished, but the rest was readily absorbed by water.

Spathous air was neither diminished, nor any other way sensibly altered, by the electric sparks.

Alkaline air, extracted from spirit of sal ammoniac, was at first almost doubled in bulk; then it was diminished a little; after which it remained without any augmentation or diminution. It became unabsoorbible by water, and by the contact of flame it exploded, like a mixture of inflammable air and a good deal of common air.

Common air was lastly tried, and it was found to give a little faint redness to the tincture of turnsole; becoming at the same time sensibly phlogisticated. The experiment was repeated thrice at different times, and in each time after the electrization it was examined by the admixture of nitrous air in Mr. FONTANA's eudiometer, and it
was

was compared with the same air not electrified; the latter always suffering the greatest diminution. In the first experiment the diminutions were $\frac{145}{300}$ and $\frac{175}{300}$; in the second, $\frac{159}{300}$ and $\frac{194}{300}$; and in the last, $\frac{149}{300}$ and $\frac{178}{300}$.

The experiments lastly described by Mr. VAN MARUM, were made with a large battery, which was charged by the above-mentioned machine. The battery consisted of 135 coated phials, all together containing about 130 square feet of coated surface; and it was generally charged to the full, by about 100 turns of the glass plates of the machine. This battery appears to have had a much greater power than what was ever obtained before by any instrument of the kind. With it they melted an iron wire, 15 feet long, and $\frac{1}{37}$ of an inch in diameter; and another time they melted an iron wire, 25 feet long, and $\frac{1}{40}$ of an inch in diameter.

With this extraordinary power of accumulated Electricity, they tried to give magnetism to needles made out of watch-springs, which

which were three and even six inches in length; and also to steel bars of nine inches in length, from a quarter to half an inch broad, and about a twelfth of an inch thick. Here follows the result of those ingenious experiments.

When the bar or needle was placed horizontally in the magnetic meridian, whichever way the shock entered, the end of the bar that stood towards the north acquired the north polarity, or the power of turning towards the north when freely suspended, and the opposite end acquired the south. If the bar, before it received the shock, had some polarity, and was placed with its poles contrary to the usual direction, then its natural polarity was always diminished, and often reversed, so that the extremity of it, which in receiving the shock looked towards the north, became the north pole, &c.

When the bar or needle was struck standing perpendicularly, its lowest end became the north pole in any case, even when the bar had some magnetism before, and was placed
with

with the south pole downwards. All other circumstances being alike, the bars seemed to acquire an equal degree of magnetic power, whether they were struck whilst standing horizontally in the magnetic meridian, or perpendicular to the horizon.

When a bar or needle was placed in the magnetic equator, whichever way the shock entered never gave it any magnetism; but if the shock was given through its width, then the needle acquired a considerable degree of magnetism, and the end of it which laid towards the west became the north pole, and the other end the south pole.

If a needle or bar, already magnetic, or a real magnet, was struck in any direction, its power was always diminished. For this experiment, they tried considerably large bars; one being 7,08 inches long, 0,26 broad, and 0,05 thick.

When the shock was so strong, in proportion to the size of the needle, as to render it hot, then the needle generally acquired no magnetism at all, or very little.

The

The experiments lastly tried with this very powerful battery were concerning the calcination of metallic substances, and the revivification of their calces. It appears that the electric shock produced both these apparently contradictory effects.

The metallic calces used in those experiments were of the purest sort; they were confined between glasses, whilst the shock was passed over them. By this means the calces were so far revivified as to exhibit several grains of the metal, large enough to be discerned by the naked eye, and to be easily separated from the rest.

As to the calcination of metals, whenever a shock was employed much greater than that which was necessary to fuse the metal, part of the metal was calcined, and dispersed into smoke. It is remarkable, that this calcination or smoke generally produced several filaments, of various lengths and thickneses, which swam in the air. It was farther observed, that those flying filaments of metallic calx, if a Conductor was presented to them, were soon attracted by it; but after the
first

first contact, they were instantly repelled, and generally broke into diverse parts.

Thus far of this extraordinary machine, to which I shall only add a wish, that machines still larger may be attempted by the opulent and the ingenious; for since this powerful machine has shewn several particulars both new and interesting, it is very probable, that larger machines and farther experiments will discover more of the hidden secrets of nature.

N° VII.

OF THE ELECTRIC PROPERTIES OF THE
TORPEDO, GYMNOTUS ELECTRICUS,
AND SILURUS ELECTRICUS.

THE electric power, by the ancients observed only in amber, and perhaps in the tourmalin, was in process of time found to be produced by glass, sulphur, resins, silk, and diverse other bodies. It has been within these forty years that its great influence has been discovered in the atmosphere; and not yet fifteen years since that power has been observed even in the animal kingdom. Three fishes have hitherto been discovered to have the singular property of giving shocks analogous to those of artificial Electricity, namely, the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*.

The ancients indeed were acquainted with this wonderful property of the first, and
probably

probably of the last of those animals, and it was from the property of giving that shock, benumbing sensation, or *torpor*, that they called the first *torpedo*; but they were utterly ignorant of the cause of it. Two distinguished writers of the last century endeavoured to explain this property upon mechanical laws, but their ingenuity was insufficient to answer for the phenomenon.

The principal discoveries, relating to the identity of the above-mentioned property of those fishes and the electric shock, were made by JOHN WALSH, Esq. F. R. S. to whose ingenuity we are indebted for the demonstration of the power of the torpedo agreeing with the electric shock in all the points of comparison in which it could be examined; and also for almost all the other discoveries which were since made relating to animal Electricity.

The three animals which, whilst alive, are possessed of an electric power, are belonging to three different orders of fish; and the few particulars, which they seem to have in common, are the power of giving the shock;

an organ in their body, now called the *electric organ*, which is employed by the animals for the exertion of that power; a smooth skin without scales; and some spots here and there on the surface of their bodies.

The torpedo, which belongs to the order of *rays*, is a flat fish, very seldom twenty inches in length, weighing not above a few pounds when full grown, and pretty common in various parts of the sea-coast of Europe. The electric organs of this animal are two in number, and placed one on each side of the cranium and gills, reaching from thence to the semicircular cartilages of each great fin, and extending longitudinally from the anterior extremity of the animal to the transverse cartilage which divides the thorax from the abdomen. In those places they fill up the whole thickness of the animal from the lower to the upper surface, and are covered by the common skin of the body, under which, however, are two thin membranes or *fasciæ*. The length of each organ is somewhat less than one third part of the length of the whole animal. Each organ consists of perpendicular columns, reaching

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from the under to the upper surface of the body, and varying in length according to the various thickness of the fish in various parts. The number of those columns is not constant, being not only different in different torpedos, but likewise in different ages of the animal, new ones seeming to be produced as the animal grows. In a very large torpedo one electric organ was found to consist of 1182 columns. The greater number of those columns are either irregular hexagons, or irregular pentagons, but their figure is far from being constant. Their diameters are generally one fifth part of an inch. " Their coats are very thin, and seem transparent, closely connected with each other, having a kind of loose net-work of tendinous fibres passing transversely and obliquely between the columns, and uniting them more firmly together : these are most observable where the large trunks of the nerves pass. The columns are also attached by strong inelastic fibres, passing directly from the one to the other."

" Each column is divided by horizontal partitions, placed over each other at ver-

small

small distances, and forming numerous interstices, which appear to contain a fluid. These partitions consist of a very thin membrane, considerably transparent. Their edges appear to be attached to one another, and the whole is attached by a fine cellular membrane to the inside of the columns. They are not totally detached from one another : I have found them adhering at different places, by blood-vessels passing from one to another."

" The number of partitions contained in a column of one inch in length, of a torpedo which had been preserved in proof spirit, appeared, upon a careful examination, to be one hundred and fifty : and this number, in a given length of column, appears to be common to all sizes in the same state of humidity, for by drying they may be greatly altered ; whence it appears probable that the increase in the length of the column, during the growth of the animal, does not enlarge the distance between each partition in proportion to that growth ; but that new partitions are formed, and added to the extremity of the column from the *fascia*."

“ The partitions are very vascular ; the arteries are branches from the veins of the gills, which convey the blood that has received the influence of respiration. They pass along with the nerves to the electric organ, and enter with them ; then they ramify in every direction, into innumerable small branches upon the sides of the columns, sending in from the circumference all around, upon each partition, small arteries, which ramify and anastomose upon it ; and passing also from one partition to another, anastomose with the vessels of the adjacent partitions.”

“ The veins of the electric organ pass out close to the nerves, and run between the gills, to the auricle of the heart.”

“ The nerves inserted into each electric organ arise by three very large trunks from the lateral and posterior part of the brain. The first of these, in its passage outwards, turns round a cartilage of the *cranium*, and sends a few branches to the first gill, and to the anterior part of the head, and then passes into the organ towards its anterior extremity.

mity. The second trunk enters the gills between the first and second opening, and, after furnishing it with small branches, passes into the organ near its middle. The third trunk, after leaving the skull, divides itself into two branches, which pass to the electric organ through the gills; one between the second and third openings, the other between the third and fourth, giving small branches to the gill itself. The nerves having entered the organs, ramify in every direction, between the columns, and send in small branches upon each partition, where they are lost."

" The magnitude and the number of the nerves bestowed on these organs, in proportion to their size, must on reflection appear as extraordinary as the phenomena they afford. Nerves are given to parts either for sensation or for action. Now if we except the more important senses of seeing, hearing, smelling, and tasting, which do not belong to the electric organs, there is no part, even of the most perfect animal, which, in proportion to its size, is so liberally supplied with nerves; nor do the nerves seem neces-

fary for any sensation which can be supposed to belong to the electric organs : and, with respect to action, there is no part of any animal, with which I am acquainted, however strong and constant its natural actions may be, which has so great a proportion of nerves *."

Thus far with the anatomical description of the animal ; we shall now proceed to describe its wonderful electric properties.

The above-described electric organs seem to be the only parts employed to produce the shock ; the rest of the animal appearing to be only the Conductor of that shock, as parts adjacent to the electric organs ; and in fact, by artificial Electricity, it has been found that the animal is a Conductor of the electric fluid. The two great lateral fins which bound the electric organs laterally, are the best Conductors.

If the torpedo, whilst standing in water or out of the water, but not insulated, be

* Mr. HUNTER's anatomical observations on the torpedo. Phil. Transf. vol. LXIII.

touched

touched with one hand, it generally communicates a trembling motion or slight shock to the hand, but this sensation is only felt in the fingers of that hand. If the torpedo be touched with both hands at the same time, one hand being applied to its under, and the other to its upper surface, a shock in that case will be received, which is exactly like that occasioned by the Leyden phial. When the hands touch the fish on the opposite surfaces, and just over the electric organs, then the shock is the strongest; but if the hands are placed in other parts of the opposite surfaces, the shocks are somewhat weaker, and no shock at all is felt when the hands are both placed upon the electric organs of the same surface; which shews that the upper and lower surfaces of the electric organs are in opposite states of Electricity, answering to the *plus* and *minus* sides of a Leyden phial. When the fish is touched by both hands on the same surface, and the hands are not placed exactly on the electric organs, a shock though weak is still received, but in that case the opposite power of the other surface of the animal seems to be conducted over the skin.

The shock given by the torpedo when in air is about four times as strong as when in water; and when the animal is touched on both surfaces by the same hand, the thumb being applied to one surface, and the middle finger to the opposite surface, the shock is felt much stronger than when the circuit is formed by both hands. Sometimes the torpedo gives the shocks so quickly one after the other, as scarcely to elapse two seconds between them; and when, instead of a strong determined stroke, it communicates only a *torpor*, that sensation is justly attributed to the successive and quick discharge of many consecutive small shocks. It is very singular, that the torpedo, even when insulated, should be capable of giving a great many shocks to persons likewise insulated.

This power of the torpedo is conducted by the same substances which conduct Electricity, and is interrupted by the same substances which are not Conductors of Electricity: hence if the animal, instead of being touched immediately with the hands, be touched by non-electrics, as wires, two
wet

wet cords, or other Conductors of Electricity, held in the hands of the experimenter, the shock will also be communicated through them. The circuit may also be formed by several persons joining hands, and the shock will be felt by them all at the same time. When the animal is in water, if the hands are put in the water, a shock will also be felt, which will be stronger if one of the hands be brought quite into contact with the fish, whilst the other hand is kept in the water at a distance from it. In short, the shock of this animal is conducted by the same Conductors which conduct that of a Leyden phial. This shock of the torpedo may be also conducted by several circuits at once, and the circuit may be considerably extended; but the shock is always weakened by lengthening or multiplying the circuit.

The shock of the torpedo cannot pass through the least interruption of continuity in the Conductors which form the circuit; so that it will not be conducted by a chain, nor will it pass through the air from one Conductor to the other, when the distance
between

between them is less than the two hundredth part of an inch ; consequently no spark has ever been observed to accompany it.

No electric attraction or repulsion could be ever observed to be produced by the torpedo, nor, indeed, by any of the electric fishes ; though several experiments have been purposely made with them.

These shocks of the torpedo seem to depend on the will of the animal ; for each effort is accompanied with a depression of his eyes, by which even his attempts to give it to non-conductors may be observed. It is not known whether both electric organs must always act together, or only one of them may be occasionally put in action by the will of the animal.

All these effects of the torpedo may be imitated by means of a large electric battery weakly charged, and furnished with Mr. LANE's electrometer, the balls of which must be put exceedingly near, or almost in contact with each other. But the properties of the *gymnotus electricus*, which we are going to describe next, will throw
more

more light on those of the torpedo, and will shew much more evidently their analogy with the power of the electric fluid dispersed through a vast surface of coated electric substance. “ But,” says Mr. WALSH, “ after
“ the discovery that a large area of rare
“ Electricity would imitate the effect of
“ the torpedo, it may be inquired, where
“ is this large area to be found in the animal?
“ we here approach to that veil of nature,
“ which man cannot remove. This, how-
“ ever, we know, that from infinite division
“ of parts infinite surface may arise, and
“ even our gross optics tell us, that those
“ singular organs, so often mentioned, con-
“ sist, like our electric batteries, of many
“ vessels, call them cylinders or hexagonal
“ prisms, whose superficies taken together
“ furnish a considerable area *.”

The *gymnotus electricus* has been frequently called *electrical eel*, on account of its superficial resemblance to the common eel; though, when accurately examined, it is found to have none of the specific properties of that animal. The *gymnotus* is found

* Phil. Transf. vol. LXIII. p. 476.

pretty frequently in the great rivers of South America. Its usual length is about three feet; but it has been said that some of them have been seen so large, as to be able to strike a man dead with the shock of their electric organs. A few of these animals were brought to England about ten years ago, which, as far as I know, were the first of the kind brought to Europe. They had been caught in Surinam river, a great way above where the salt-water reaches. It was with those identical fishes that Mr. WALSH made many discoveries relating to their electrical properties, and the experiments which shew those properties were publicly exhibited in London, during several months.

The subject of Animal Electricity was considerably advanced by the discovery of the spark, with which the shock of the gymnotus was attended; for, notwithstanding the previous discoveries relating to the torpedo, and the actual possibility of imitating the effects of that animal's extraordinary power by means of a large battery weakly charged with artificial Electricity, yet the scrupulous philosophers still suspected that the power of the torpedo might be something different

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ent from Electricity, since the two principal characteristics of Electricity, namely the spark and the attraction, had never been discovered in the torpedo; and at the same time it was difficult to conceive the manner in which the electric fluid might be generated, accumulated, and discharged in an animal, which, at least in its usual state of existence, is a Conductor of Electricity, and is surrounded by a fluid which is likewise a Conductor of that power. This indeed still remains a profound secret; and it is difficult to say, whether any future experiments will ever disclose it. But the spark having been discovered with the gymnotus, the analogy between its power and Electricity is rendered considerably more evident, and it would be scepticism to doubt, of the property of the torpedo being derived from the same cause as that of the gymnotus.

In order to proceed regularly, I shall now begin with the description of the animal, and shall then enumerate its electric properties, in a very concise manner.

A gymnotus of three feet length, is generally

rally between ten and fourteen inches in circumference, about the thickest part of its body. The electric power of this animal being much greater than that of the torpedo, its electric organs are accordingly a great deal larger, and indeed that part of its body which contains most of the animal parts, or the parts common to the same order of fishes, is considerably smaller than that which is subservient to the electric power; though the latter must naturally derive nourishment and action from the former.

The head of the animal is large, broad, flat, smooth, and impressed with various small holes. The mouth is rather large, but the jaws have no teeth, so that the animal lives by suction, or by swallowing the food entire. The eyes are small, flattish, and of a bluish colour, placed a little way behind the nostrils. The body is large, thick, and roundish for a considerable distance from the head, and then diminishes gradually. The whole body, from a few inches below the head, is distinguished into four longitudinal parts, clearly divided from each other by lines. The carina begins a few
few

few inches below the head, and widening as it proceeds, reaches as far as the tail, where it is thinnest. It has two pectoral fins, and the *anus* is situated on the under part, more forward than those fins, and of course not far distant from the *rostrum*.

This animal has two pair of electric organs, one pair being larger than the other, and occupying most of the longitudinal parts of the body. They are divided from each other by peculiar membranes. “ The structure of these organs is extremely simple and regular, consisting of two parts, *viz.* flat partitions or *septa*, and cross divisions between them. The outer edges of these *septa* appear externally in parallel lines nearly in the direction of the longitudinal axis of the body. These *septa* are thin membranes placed nearly parallel to one another : their lengths are nearly in the direction of the long axis, and their breadth is nearly the semidiameter of the body of the animal. They are of different lengths, some being as long as the whole organ. I shall describe them as beginning principally at the anterior end of the organ, although a few begin

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along

along the upper edge; and the whole, passing towards the tail, gradually terminate on the lower surface of the organ, the lowermost at their origin terminating soonest. Their breadths differ in different parts of the organ. They are in general broadest near the anterior end, answering to the thickest part of the organ, and become gradually narrower towards the tail; however, they are very narrow at their beginnings or anterior ends. Those nearest to the muscles of the back are the broadest, owing to their curved or oblique situations upon these muscles, and grow gradually narrower towards the lower parts; which is in a great measure owing to their becoming more transverse, and also to the organ becoming thinner at that place. They have an outer and an inner edge: the outer is attached to the skin of the animal, to the lateral muscles of the fin, and to the membrane which divides the great organ from the small; and the whole of their inner edges are fixed to the middle partition, to the air bladder, and three or four terminate on that surface which incloses the muscles of the back. These *septa* are at the greatest distance from one another at their exterior

edges

edges, near the skin, to which they are united; and as they pass from the skin towards their inner attachments they approach one another: sometimes we find two uniting in one. On that side next to the muscles of the back they are hollow from edge to edge, answering to the shape of those muscles, but become less and less so towards the middle of the organ; and from that towards the lower part of the organ they become curved in the other direction. At the anterior part of the large organ, where it is nearly of an equal breadth, they run pretty parallel to one another, and also pretty straight; but where the organ becomes narrower, it may be observed in some places that two join or unite into one, especially where a nerve passes across. The termination of this organ at the tail is so very small, that I could not determine whether it consisted of one *septum* or more. The distances between these *septa* will differ in fishes of different sizes. In a fish of two feet four inches in length I found them $\frac{1}{27}$ of an inch distant from one another, and the breadth of the whole organ, at the broadest part, about an inch and a quarter, in which space were

34 *septa*. The small organ has the same kind of *septa*, in length passing from end to end of the organ, and in breadth passing quite across, they run somewhat serpentine, not exactly in straight lines. Their outer edges terminate on the outer surface of the organ, which is in contact with the inner surface of the external muscle of the fin, and their inner edges are in contact with the centre muscles. They differ very much in breadth from one another; the broadest being equal to one side of the triangle, and the narrowest scarcely broader than the point or edge. They are pretty nearly at equal distances from one another; but much nearer than those of the large organ, being only about $\frac{1}{36}$ part of an inch asunder: but they are at a greater distance from one another towards the tail, in proportion to the increase of breadth of the organ. The organ is about half an inch in breadth, and has fourteen *septa*: these *septa*, in both organs, are very tender in consistence, being easily torn; they appear to answer the same purpose with the columns in the *torpedo*, making walls or butments for the subdivisions, and are to be considered as making so many distinct

ting organs. These *septa* are intersected transversely by very thin plates or membranes, whose breadth is the distance between any two *septa*, and therefore of different breadths in different parts; broadest at that edge which is next to the skin, narrowest at that next to the centre of the body, or to the middle partition which divides the two organs from one another. Their lengths are equal to the breadths of the *septa* between which they are situated: there is a regular series of them continued from one end of any two *septa* to the other; they appear to be so close as even to touch. In an inch in length there are about 240, which multiplies the surface in the whole to a vast extent *."

The nerves which go to the electric organs of the gymnotus, as well as of the torpedo, are much larger than those which supply any other part of the body. The electric organs of the gymnotus are supplied with nerves from the spinal marrow, and

* Mr. HUNTER's account of the Gymnotus Electricus. Phil. Transf. Vol. LXV.

they come out in pairs between the vertebræ of the spine.

The gymnotus possesses all the electric properties of the torpedo, but in a superior degree. His shock is conducted by the Conductors of Electricity, and interrupted by the non-conductors of the electric fluid. Hence the shock is communicated through water, without the immediate contact of the animal, or through any other proper circuit; but the stronger shock is received by touching the animal when out of the water; and the best way to receive strong shocks, is to apply one hand towards the tail, and the other towards the head of the animal. In this manner I have often received shocks, which I felt not only in my arms, but even very forcibly in my breast. If the animal be touched only with one hand, then a kind of tremor is felt only in that hand, which though stronger, is quite analogous to the sensation communicated by the torpedo when touched in the like manner. The gymnotus's power of giving shocks is also depending on the will of the animal, so that sometimes he gives very strong shocks, and

and at other times very weak ones, but he gives the strongest shocks when provoked by being frequently and roughly touched.

When small fishes are put into the water wherein the gymnotus is kept, they are generally stunned or killed by a shock, and then they are swallowed, if the animal is hungry. The fishes which are stunned by the gymnotus may often be recovered by being speedily removed into another vessel of water.

The strongest shocks of the gymnotus will pass a very short interruption of continuity in the circuit. Thus they will be conducted by a chain, especially when it is not very long, and is stretched, so as to bring its links into better contact. When the interruption is formed by the incision made by a pen-knife on a slip of tin-foil that is pasted on glass, and that slip is put into the circuit, the shock in passing through that interruption will shew a small but vivid spark, plainly distinguishable in a dark room.

Mr. WALSH made another remarkable discovery with the gymnotus, which he shewed at his house to various ingenious persons : it was a new sort of sense in the animal, by which he knew when the bodies which came near him were such as could receive the shock, (*viz.* Conductors) and when they were of the contrary nature; in the former of which cases the animal gave the shock, but not in the latter. In order to shew this wonderful property, divers experiments were made, but the most convincing one was the following :—the extremities of two wires were dipped into the water of the vessel wherein the animal was kept, then they were bent, and extended a great way, and lastly terminated in two separate glasses full of water. These wires being supported by non-conductors at a considerable distance from each other, it is plain that the circuit was not complete ; but if a person put the fingers of both his hands into the glasses wherein the wires terminated, *viz.* those of one hand into one, and those of the other hand into the other glass, then the circuit was complete. Now it was constantly observed, that whilst the above-described circuit

cuit remained interrupted, the animal never went purposely near the extremities of the wires, as he used to do when willing to give the shock : but the moment that the circuit was completed, either by a person or any other Conductor, the animal immediately went towards the wires, and gave the shock ; though the completion of the circuit was performed quite out of his sight.

Several other particulars, not only concurring to prove the above-mentioned property, but otherwise interesting, were ascertained by Mr. WALSH ; but for these we must wait till that ingenious gentleman will favour the public with a particular account of his researches.

The third fish which is known to have the power of giving the shock, is found in the rivers of Africa, but we have a very imperfect account of its properties *.

* Messrs. ADANSON and FORSKAL make a short mention of it, and Mr. BROUSSONET describes it, under the French name of *le Trembleur*, in the Hist. de l'Academie Royale des Sciences, for the year 1782.

This animal belongs to the order which the naturalists call *silurus*; hence it is commonly called *silurus electricus*. Some of those fishes have been seen even above twenty inches long.

The body of the *silurus electricus* is oblong, smooth, and without scales; being rather large, and flattened towards its anterior part. The eyes are of a middle size, and are covered by the skin, which envelopes the whole head. Each jaw is armed with a great number of small teeth. About the mouth it has six filamentous appendices, *viz.* four from the under lip, and two from the upper; the two external ones, or farthest from the mouth on the under lip, are the longest. The colour of the body is greyish, and towards the tail it has some blackish spots.

The electric organ seems to be towards the tail, where the skin is thicker than on the rest of the body, and a whitish fibrous substance, which is probably the electric organ, has been distinguished under it.

It is said that the *filurus electricus* has the property of giving a shock or benumbing sensation like the torpedo, and that this shock is communicated through substances that are conductors of Electricity; but no other particular about it is known with any considerable degree of certainty.

An inquisitive mind will immediately enquire, for what purpose has nature furnished those animals with so singular a property. But the present knowledge of the subject seems to furnish no other answer, except, that they are endowed with the power of giving the shock for the sake of securing their prey, by which they must subsist, and perhaps of repelling larger animals, which might otherwise annoy them.

The ancients considered the shocks given by the torpedo as capable of curing various disorders; and a modern philosopher will hardly hesitate to believe their assertions, after that Electricity has been found to be a remedy for many diseases.

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TH E mineral acids are much better conductors than other liquids, and the conducting power of water is considerably increased by the admixture even of a small quantity of any of them.

Quicksilver excites glass negatively.

Very good tourmalins, it is said, have been found in the mountains of Saxony, near Freyberg.

To Chap. V. Exp. I.—The pin or pointed body that is presented to the rubber must not be very sharp; otherwise the pencil of light is rarely observed.

To Vol. II. p. 82.—The lower extremity of the silver wire must be formed into a globule, in order to prevent the corks getting off. This is easily done, by putting the extremity of the wire in the flame of a candle.

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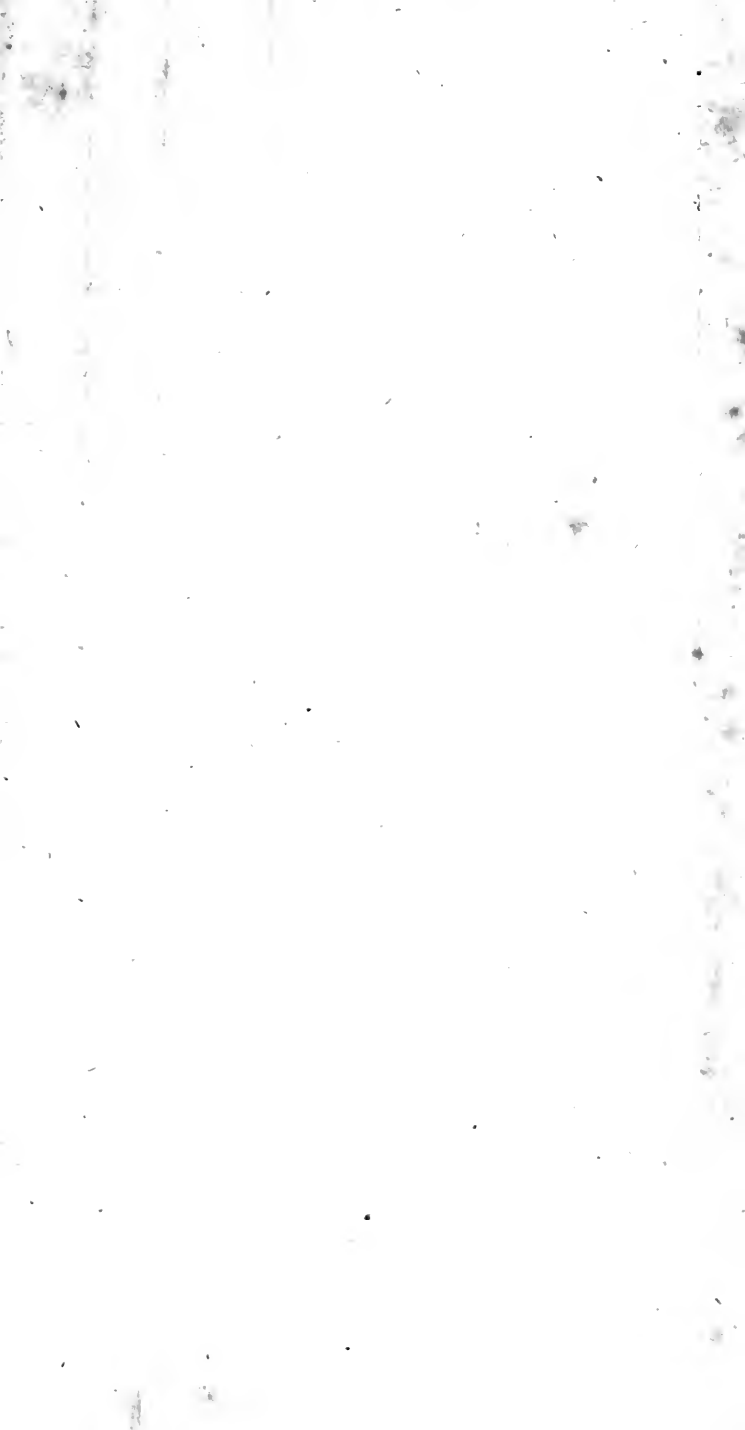
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